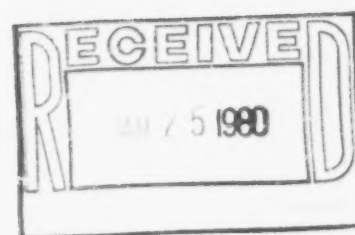


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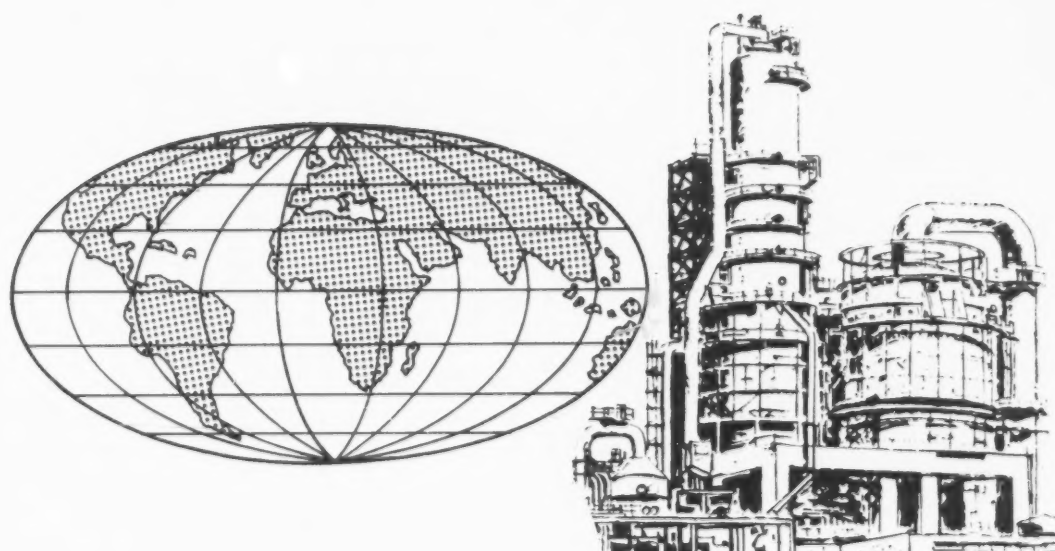
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TRENDS IN INTERNATIONAL PETROLEUM REFINING

FOURTH EDITION

JOHN C. LANE



ETHYL INTERNATIONAL

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The first survey in this series, published in 1964, explored petroleum-refining trends in six major refining nations whose economic growth during the previous ten years had been unusually rapid.

In 1967, we surveyed the same six nations to determine the extent to which the trends apparent in 1964 had continued and to identify, if possible, the reasons for any marked deviations from them. We also surveyed the six major South American refining nations for the first time.

In 1975, eleven years after our original study, we took a long retrospective look at what had transpired over the 20-year period for which we had compiled trend data (i.e., 1955 through 1974). That just included, but did not go beyond, the initial impact of the 1973-74 Arab oil embargo and the approximate quadrupling of crude-oil prices by the Organization of Petroleum Exporting Countries (OPEC).

Now, enough time has elapsed for preliminary assessment of changes forced by high-priced crude oil and near-monopoly control of crude-oil supply.

SCOPE OF PRESENT SURVEY

Like our previous updating studies, this fourth survey adds a number of countries not previously covered. That seems desirable because future rapid rates of domestic demand and/or refinery production can reasonably be expected in several such countries.

Our original (1964) study covered all nations then having 1,000,000 b/d (50 million mT/yr) or more of crude-distillation capacity – except the United States, Canada, and the U.S.S.R. The U.S. and Canada were omitted because their gasoline-oriented refining situations were not comparable with those of the other major refining nations. Unavailability of data prevented inclusion of the U.S.S.R.

As mentioned, our 1967 survey added South America's six major refining nations. And our 1975 survey expanded coverage to those refining nations of Europe, Africa, the Middle East, and the Far East for which adequate data were available.

APPROACH AND FORMAT

For the convenience of the greatest number of our readers, all refining capacities and data on product demand have been converted to metric tons (mT), as a basic international unit of measurement.

Because the densities of crude oils and petroleum products vary somewhat from source to source, data converted into metric tons from the volumetric measures (barrels or kilolitres) employed in some reporting countries may be slightly higher or lower than was actually the case. However, since the same conversion factors have been used for a given country over the entire time span surveyed, this will have no effect on indicated trends.

As in our previous surveys, we again have plotted our trend charts on semilogarithmic coordinates to show whether growth has been taking place at some constant compound annual

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rate and to determine the pattern, if any, of changes in rates of growth.

As noted in our earlier surveys, any attempts to extrapolate past or present trends into the future are subject to the uncertainties of general economic conditions and special governmental control measures, such as production restraints, protective taxes, and allocation or rationing. To those factors now must be added unilateral control of raw-material availability and pricing by the oil-producing nations. As noted in our 1975 survey, "The effect of the latter (crude-oil pricing) is reflected in the 1973-74 downturn shown in the charts for most of the countries surveyed. If the combination of high crude-oil prices and possibly curtailed supply continues, it can be expected to significantly depress growth of the petroleum-refining industry all around the world."

THE PAST TEN YEARS IN REVIEW

Worldwide response to post-1973 crude-oil prices is typified by the curves of Figure 1 for the nations we first surveyed in 1964. Here, conventional arithmetic coordinates have been used to avoid underemphasizing the abruptness of the resulting sharp slump in demand for petroleum products.

In Figure 1, we see the end of one trend and, perhaps, the beginning of another. In all cases, demand reversed direction drastically after 1973. In Japan, it shows signs of a renewed, slower upward trend. In other countries (West Germany, France, and Italy), the upturn of 1976 was followed by a downturn in 1977. And in the

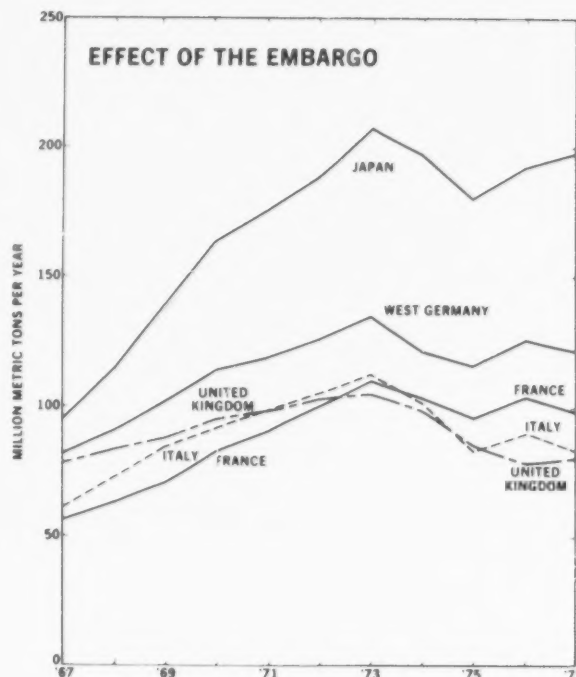


Figure 1. Domestic Demand for Petroleum Products Before and After 1973-74 Oil Embargo

United Kingdom, demand declined steadily from 1973 through 1976, flattening out during 1977.

In Japan's case, 1973 terminated six years of 14% annual growth in domestic demand for petroleum products. For West Germany, France, and Italy, 1973 saw the end of demand growth at average annual rates of 9%, 12%, and 11%, respectively. And for the United Kingdom, 1973 ended a gradually flattening period of growth at an average annual rate of 5%.

What has happened since 1973 hardly constitutes a trend. As shown in Table 1, previously

TABLE 1
Changes in Domestic Demand Since 1973

Nation	1967-73	Percentage Change from Previous Year			
		1974	1975	1976	1977
Japan	14	-4.3	-4.0	6.7	3.1
West Germany	9	-9.7	-4.1	8.6	-3.2
United Kingdom	5	-6.7	-7.1	-7.1	2.5
Italy	11	-8.9	-18.6	8.4	-6.7
France	12	-5.5	-7.7	7.3	-3.9

TABLE 2
Typical Domestic Demand Patterns

% by Weight of Total Domestic Demand, 1977 vs 1967*

Product	U.S.A.	Japan	W. Germany	U.K.	Italy	France
Gasoline	42 (41)	12 (10)	18 (16)	21 (19)	13 (16)	17 (19)
Jet Fuel & Kerosene	7 (9)	11 (7)	2 (2)	5 (7)	2 (4)	2 (2)
Distillates	18 (18)	17 (6)	48 (41)	24 (17)	24 (10)	38 (39)
Residual	16 (16)	45 (58)	18 (22)	34 (37)	42 (60)	28 (26)
Other	17 (16)	15 (19)	14 (19)	16 (20)	19 (10)	15 (14)

* 1967 percentages are in parentheses

steady rates of growth deteriorated into sharp declines in 1974 and 1975. The apparent recovery of 1976 (except in the United Kingdom) probably was more the bounce that follows a hard fall than the beginning of a sound new trend. Surely the oil-short nations of the world have learned a costly lesson. How they will eventually meet their massive energy needs remains to be seen.

EASTERN HEMISPHERE NATIONS

Before looking at the major Eastern Hemisphere nations individually, in depth, we might do well to consider some broad general similarities and differences in their domestic-demand patterns. Unlike the U.S.A. (see Table 2), all of them are fuel-oil oriented. Distillate and residual fuel oils, combined, account for about 60% of total product demand in each of the countries.

Gasoline accounts for only 10-20% of total demand, compared with its 40% share in the United States. Moreover, in two of the nations, Japan and Italy, residual fuel oil is still by far the largest-volume product.

Since the populations of these nations differ considerably, with that of Japan being twice that of France, direct comparison of demand levels could be misleading. Therefore, Table 3 breaks down some salient 1977 statistics into per-capita figures. As can be seen, annual consumption of petroleum products ranges from about 1.5 metric ton (11 barrels) in the United Kingdom and Italy to about 2.1 mT (15 barrels) in West Germany. Per-capita gasoline consumption ranges from 0.20 mT (about 1.7 barrels) in Italy to 0.37 mT (3.1 barrels) in West Germany. Japan, Italy, and the U.K. use only about half as much distillate fuel per person as does France and only about a third

TABLE 3
Motor Vehicle and Petroleum-Products Picture, 1977

Nation	Population	Persons per Vehicle			Domestic Demand per Person, mT/yr			
		Cars	Trucks	Both	Gasoline	Distillate	Residual	Total
Japan	104,660,000	5.3	8.6	3.3	0.22	0.31	0.85	1.89
West Germany	59,180,000	2.9	39.3	2.7	0.37	1.00	0.37	2.09
United Kingdom	55,346,000	3.9	28.9	3.4	0.29	0.34	0.56	1.52
Italy	54,080,000	3.4	43.3	3.1	0.20	0.38	0.66	1.56
France	51,260,000	3.0	21.9	2.7	0.33	0.72	0.54	1.93
United States	203,184,000	1.8	6.8	1.4	1.54	0.88	0.85	4.68

as much as West Germany. For Japan and Italy, this can be largely explained by their warmer climate, which reduces the need for central home-heating systems. In the United Kingdom, coal is still the economically favored space-heating fuel. And North Sea natural gas seems likely to become the U.K.'s preferred home-heating fuel in the near future.

As was seen in Table 2, gasoline accounts for a relatively small share of total product demand in all of the Eastern Hemisphere countries, ranging from 12% in Japan to 21% in the United Kingdom. Per-capita car ownership has grown considerably in the last few years, but it still is much lower than in the United States. Whereas the U.S. has one car for every two persons, the figures range from one for three persons in France and West Germany to one for five persons in Japan. The past dozen years have seen the persons-per-car ratio shrink rapidly, however, in all of these nations. In 1966, it was 33 to 1 in Japan, 8 to 1 in Italy, and 5 to 1 in France, West Germany, and the United Kingdom.

Comparing the gasoline-production capacities shown in Table 4 with the gasoline-demand patterns shown in Table 2 points up the fact that none of the major Eastern Hemisphere nations has the cracking capacity to increase naphtha yield very much. Most of the virgin naphtha they produce in their distillation of crude oil is reformed to make gasoline. This means that naphtha for manufacture of chemical inter-

mediates — ethylene, propylene, butadiene, benzene, toluene, xylenes — is usually in critically short supply. Yet a recent study* of chemical-feedstock needs by 24 industrialized nations showed most of their demand for those intermediates will have to be met from naphtha — imported if need be.

The findings of another study of world naphtha demand, conducted by Chase Manhattan Bank, indicates that the portion going into chemicals production will increase from about 15% in 1977 to 18% by 1980. As can be seen from Table 5, the percentage of total naphtha production required for chemicals is much higher in the rest of the world than it is in the United States, where cracking capacity is a much higher portion of total distillation capacity (see also Table 4).

Because olefinic cracked naphthas are attractive gasoline blending stocks, the first of these surveys suggested that, in countries where catalytic crackers are scarce, some refiners might find joint construction and shared use to be feasible and profitable. This now appears to be an idea whose time has come. In its November 6, 1978, issue, the Oil and Gas Journal terms the downstream-processing complex planned by Texaco and Gulf for joint use by their nearly adjacent refineries on the Milford Haven (Wales) estuary

*European Chemical News, 9 June 78, p. 36

TABLE 4
Gasoline Production Capacity — Cracking and Reforming

% of Crude Distillation Capacity*			
Nation	Cracking (C)	Reforming (R)	Gasoline Potential (C+R)
Japan	5 (6)	9 (10)	14 (16)
West Germany	3 (4)	11 (12)	14 (16)
United Kingdom	5 (7)	13 (15)	18 (22)
Italy	5 (8)	8 (12)	13 (20)
France	4 (6)	11 (13)	15 (19)
United States	30 (40)	19 (22)	49 (62)

*1966 percentages are in parentheses

TABLE 5
World Naphtha Demand and Percent Going to Chemicals*

Area	1977		1980		1985	
	10 ⁶ mT	% Chem	10 ⁶ mT	% Chem	10 ⁶ mT	% Chem
United States	364	6.3	377	7.7	387	10.9
Rest of World	568	21.0	635	20.9	745	22.0
Total	932	15.2	1,012	16.0	1,132	18.2

*Source: Chase Manhattan Bank; Oil & Gas Journal, 26 June 78, p. 64.

"one of the most ingenious projects in the refining world – the building of the downstream end of a modern high-conversion refinery – the end that European refiners sorely need." As a result, the Journal points out "250,000 b/d (about 14 million mT/yr) of European refining capacity can more than double its output of gasoline and naphtha."

Another grassroots catalytic-cracking project recently announced in Western Europe is a joint venture by Amoco (U.K.) Ltd. and Murco Petroleum Ltd. to build a shared-use 32,000-b/d (1.6 million-mT/yr) catalytic cracker at Amoco's Milford Haven refinery. Mobil Oil Co. Ltd. plans to add a 38,000-b/d (1.9 million-mT/yr) fluid cat cracker at its Coryton refinery in Essex, England. In France, Elf Aquitaine has almost completed a

20,000-b/d (1 million-mT/yr) fluid catalytic-cracking complex at its Grandpuits refinery, which will process both local feed and feed pipelined from Elf's Gargenville refinery about 150 km (90 miles) away. And in the Netherlands, British Petroleum's Dutch affiliate plans to add a 40,000-b/d (2 million-mT/yr) fluid cat cracker at its 500,000-b/d (25 million-mT/yr) Rotterdam refinery.

Now, having seen some of the forces currently at work in (and on) the major Eastern Hemisphere refining nations, let's take closer looks at each of those nations individually. We will start with Japan, the world's third largest consumer of petroleum products (behind the U.S.A. and the U.S.S.R.) – and over the past 30 years by far the fastest growing.

JAPAN

Current Situation

During the past 10 years, Japanese crude-distillation capacity was expanded an average 9% per year. As shown in Figure J-1, that expansion occurred at a rapid 11% annual rate over the first eight of those years, tapering off to practically nil after the oil shock of 1973-74 had time to affect projects not already underway when it hit. The carryover effects of projects too far advanced to cancel, plus an abrupt flattening of domestic demand in the face of sharply increased prices, account for the past four years' imbalance be-

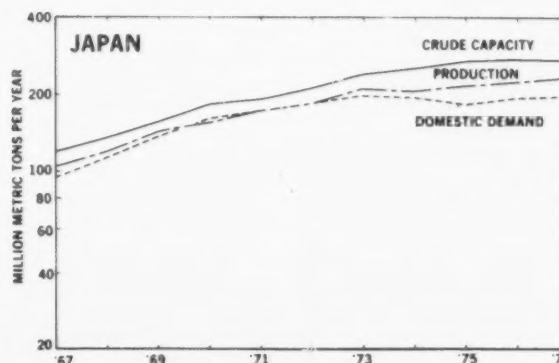


Figure J-1. Trends in Japanese Domestic Demand, Production, and Crude Capacity

tween demand on the one hand and refinery capacity and output on the other.

The impact of the oil shock on Japan can be adequately comprehended only when previous rates of growth are recalled. From 1956 through 1970, Japanese domestic demand and refinery output grew at annual rates ranging from 15% to 25% – and, during the first 10 years of that period, the rate was an almost uniform 25%. A general economic recession slowed annual growth rates to about 7.5% in the 1971-73 period. And,

with the added effect of quadrupled oil prices, they turned negative in 1974. Since the end of 1975, they have risen about 4% per year, perhaps beginning a new, slower, growth trend.

As shown in Figure J-2, Japan's domestic-demand pattern has been changing gradually toward lighter products. But heavy fuel oils still are the dominant product, accounting for 46% of total demand, compared with 56% in 1967. Meanwhile, light fuel oils' share of the market has risen from 13% to 15%, that of jet fuel and kerosene from 8% to 11%, that of petrochemical naphtha from 10% to 14%, and that of gasoline from 11% to 12%.

Coincident with Japan's rapid postwar industrial growth, demand for heavy fuel oils increased almost sixfold from 1955 through 1963 – from less than 6 million mT/yr (about 110,000 b/d) to almost 33 million mT/yr (600,000 b/d). It continued to grow quite rapidly until 1971, but not at the phenomenal 25% annual rate of the 1955-63 period. During the first three years of the current survey period (1968-70), it rose at an average annual rate of 19%. The general economic slowdown of 1971-72 slowed its growth to less than 3% annually. But it rose to almost 8% in 1973 – then nosedived to a 6% decline in 1974 and a further 18% drop in 1975. Since then, it has

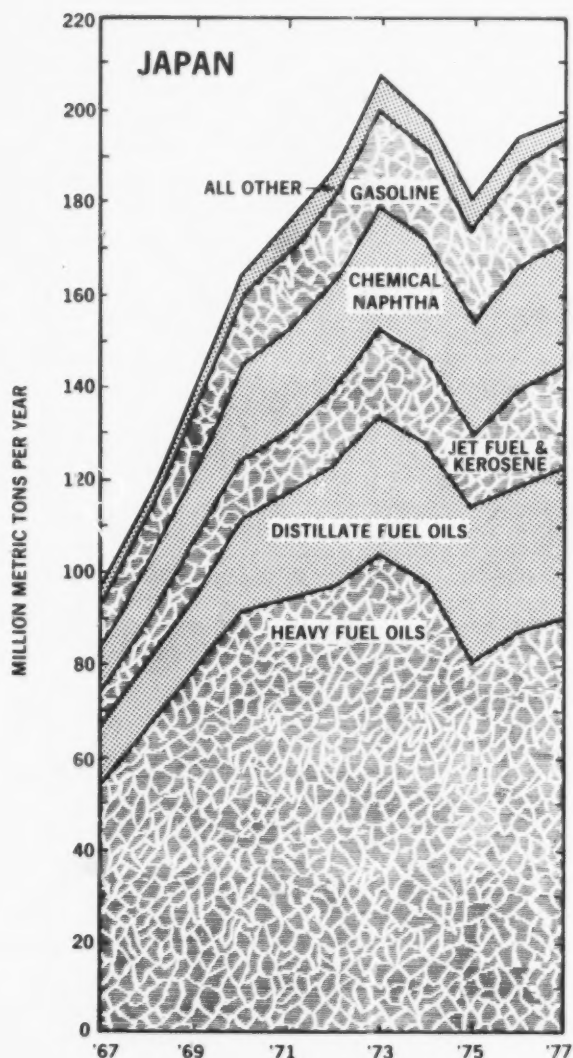


Figure J-2. Distribution of Japanese Demand Among the Major Products

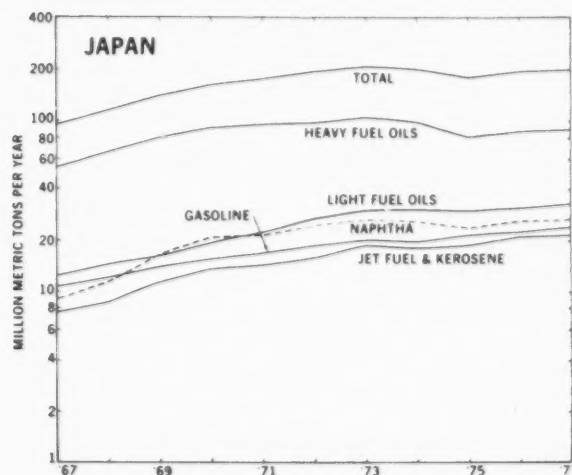


Figure J-3. Rates of Growth in Japanese Domestic Demand for Major Products

resumed growth at rates of 8% in 1976 and 3% in 1977. As shown in Figure J-3, the trends, if any, in Japanese demand for heavy fuel oils have been slowing and erratic.

Demand for light fuel oils has, however, shown a definite trend upward in the 1967-77 survey period. Prior to the 1973-74 oil shock, it was rising at an average rate of 16% per year. After three years of little or no growth, it rose almost 6% last year.

Japanese demand for petrochemical naphtha also rose an average 16% per year over the 1967-73 period. But it stagnated during the next three years, largely as a result of sharply higher crude-oil and refined-product prices in the world market.

Except for a temporary post-shock stagnation in 1974, Japanese demand for gasoline grew a fairly steady 7% annually over the entire survey period – somewhat faster in the pre-1974 years than afterward.

Outlook for the Future

Faced with importing essentially all of the crude oil it consumes, at prevailing world prices, Japan reduced those imports 5% in its fiscal year 1974 (ended March 31, 1975). It also took a new, hard look at its future energy requirements and petroleum's role in meeting them. In fiscal 1975, Japan imported 286 million kilolitres (about 246 million mT) of crude oil to meet a total energy requirement from all sources of 390 million kilolitres of oil equivalent – i.e., 73% of its total energy consumption came from imported oil. Its long-range forecast of energy supply and demand, updated in June 1977, foresees a 1985 energy requirement of 660-700 million kilolitres of oil equivalent, of which 432-505 million kilolitres will have to be met with imported crude oil. The low numbers in the forecast assume utmost conservation and development of alternative sources. The "policy" target for 1990, which assumes continuing conservation and development efforts, is for holding energy demand to 792 million kl of oil equivalent and oil imports to 452 million kl. So, for the foreseeable future, Japan

will continue to rely on imported crude oil for more than half of its total energy supply.

At the Ninth World Petroleum Congress, Shigeru Fujinuma, deputy manager of the Petroleum Association of Japan's Technology and Environmental Department, pointed out that the nation's refinery production system "is, in principle, designed for self-sufficiency of gasoline and naphtha. . . . All crude-oil distillation and gasoline units are installed or expanded under an approval system. At the beginning of each fiscal year, demand is estimated. Refiners then submit expansion plans for approval by the Petroleum Council. . . . However, we must bear in mind that, due to the overall demand-suppression policy that has been in effect since the latter half of 1974, the demand for petroleum products has decreased rapidly; i.e., demand compared with the previous year was lower for the first time since the end of the war, and demand in the future is not expected to increase much. It is presumed that the current approved capacity, then, will be sufficient for several years."

In November 1973, proposed additions to Japanese crude-distillation capacity were approved through fiscal 1977, by the end of which total capacity would have reached 370 million mT/yr, according to Mr. Fujinuma. As can be seen from Table J-1, the Ministry of International Trade and Industry's current five-year forecast of demand for the major petroleum products predicts an overall growth of 20% during the 1977-81 period. Allowing for the recent percentages of "other" products, 1981 total demand would be expected to be about 251 million mT. Thus, considerably more new crude-distillation capacity was approved than will be needed even by the end of 1981.

Quoting the August 18, 1975, issue of Japan Petroleum News, "The petroleum crisis of 1973 was the turning point. The high petroleum demand growth period has come to an end, and the total refinery capacity of about 5,600,000 b/d (280 million mT/yr) has now become too big for the Japanese economy. . . . Judged from the long-term estimates for petroleum products, the existing refinery capacity will be able to fulfill the

TABLE J-1
Five-Year Forecast of Japanese Demand for Major Products
 (fiscal year begins in April of year named)

Product	Millions of Metric Tons				
	1977	1978	1979	1980	1981
Gasoline	23.5	24.5	25.5	26.5	27.4
Naphtha	29.3	30.8	32.7	33.1	36.4
Jet Fuel	1.8	1.9	2.0	2.1	2.3
Kerosene	20.0	21.2	22.4	23.7	25.0
Gas Oil	14.9	15.7	16.4	17.0	17.7
Fuel Oils	<u>114.2</u>	<u>116.7</u>	<u>120.9</u>	<u>127.4</u>	<u>135.3</u>
Total	203.7	210.8	219.9	229.8	244.1

supply requirement for 5 to 6 years to come. Hence, the Resources and Energy Agency wants to re-postpone the already authorized construction and expansion of topping facilities." Completion dates for those facilities, originally scheduled for various times in 1976 or 1977, were postponed for six months to a year in September 1974. Since that time, Japan's crude-distillation capacity has remained essentially constant at a reported 5,940,360 barrels per stream day, or about 297 million mT/yr.

Since Japan neither imports nor exports major quantities of petroleum products, its refinery output – hence capacity – should closely approximate domestic demand (see Figure J-1). Facilities for producing gasoline (see Figure J-5) "are authorized in such a way that their capacities properly correspond to the capacity of the atmospheric-distillation system, and authorization is given after approval is given for installation of the atmospheric-distillation system," Mr. Fujinuma explained at the World Petroleum Congress.

"While cracking-type gasoline is used in the United States, most of the automotive gasoline used in Japan is of a reformed type, with the main component being straightrun gasoline," Mr. Fujinuma pointed out. "The catalytic-reforming capacity in Japan's refineries at the end of 1974

was 561,000 b/d (about 24.1 million mT/yr) with 57 units," he said. "Catalytic-cracking capacity was 327,000 b/d (about 14 million mT/yr) with 19 units."

Since then, little changes have been made in Japan's gasoline-production capacity. As can be seen from Figure J-4, the nation's combined cracking and reforming capacity has continued to exceed domestic demand for gasoline by a comfortable margin. At the end of 1977, that capacity totaled about 39 million mT/yr, compared with a gasoline demand of less than 24 million mT/yr. However, Japan's heavy demand for petrochemical naphtha must be kept in mind when assessing the adequacy of its facilities for producing gasoline-range fractions. Demand for naphtha totaled almost 27 million mT in 1977, making combined demand for gasoline and naphtha about 50 million mT, or 25% of total petroleum-product demand.

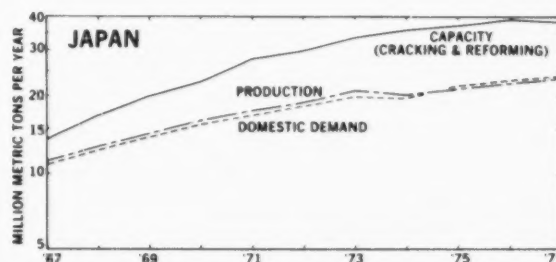


Figure J-4. Growth in Japanese Gasoline Demand, Output, and Capacity

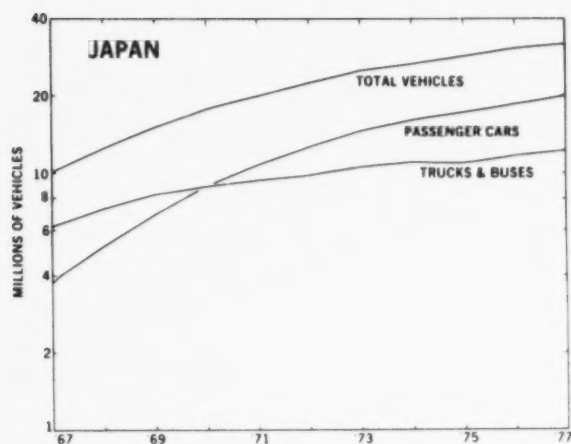


Figure J-5. Rates of Growth in Japan's Motor-Vehicle Population

As noted in our 1967 survey, Japanese motor-vehicle registrations began a very steep rate of growth in 1960 and showed an average annual increase of 37% from year-end 1959 to year-end 1966. During that time, they increased sevenfold – to 7.8 million. By that time, the growth rate was slowing somewhat, however. It averaged about 26% annually from 1965 through 1968, declining to 21.2% in 1969 (see Figure J-5). This slow-down in annual rate of growth continued throughout the rest of the survey period, with the rate rather steadily declining from 16.2% in 1970 to 11.6% in 1973 and dropping to 7.1% in 1974. Since then, total registrations have grown an average 6% per year. As shown in Figure J-5, passenger-car registrations exceeded those of trucks and buses in 1970, for the first time, and

now account for about 62% of total Japanese motor-vehicle registrations. Over the 1967-77 survey period, the total registrations tripled.

Gasoline Quality

As shown in Table J-2, the antiknock quality of Japanese gasolines, both premium and regular, was higher in 1969 than it was in 1977. In mid-1970, the limit on lead-antiknock concentration was reduced from 0.8 gram per litre to 0.3 gram per litre. Then, early in 1975, the environmental authorities ruled that all regular-grade gasoline henceforth must be lead-free. Like other high-octane gasolines containing large amounts of aromatic blending stocks from catalytic reforming, Japanese gasolines have tended to have rather high sensitivities (RON minus MON). In the 1960's and early 1970's, judicious use of alkyl-lead antiknocks enabled Japanese refiners to avoid the high sensitivities and poor front-end antiknock quality that are characteristic of gasolines deriving their high Research ratings solely from severely reformed naphthas. With the phase-down of lead in both grades of Japanese gasoline – and now with its complete elimination from the regular grade – this no longer is true. In March 1970, the Japanese regulars (averaging 0.015 g Pb/litre) had a sensitivity of only 4.5. In April 1975, analysis of 12 different Tokyo regulars (unleaded by law) showed them to have an average sensitivity of 8.7 – and an aromatics content of 41%, compared with 30% for the 1970 leaded regulars.

TABLE J-2

Average Antiknock Quality of Japanese Gasolines

	1969	1970*	1974	1975†	1976	1977
Premium RON	99.5	97.2	97.9	97.3	97.6	97.4
Pb, g/litre	0.61	0.19	0.15	0.19	0.19	0.20
Regular RON	91.0	90.0	90.6	90.3	90.5	90.3
Pb, g/litre	0.30	0.16	0.06	—	—	—

*On July 1, 1970, the limit on lead concentration was reduced from 0.8 g/litre to 0.3 g/litre.

†On February 1, 1975, all regular-grade gasoline was made lead-free by law.

WEST GERMANY

Current Situation

Until recently, West Germany's refining capacity was in reasonable balance with domestic demand, as shown in Figure G-1 and reported in our earlier surveys. But after the 1973-74 oil embargo and sharp rise in prices for imported crude, demand dropped abruptly. Capacity continued to expand for more than another year, however, as projects started earlier came on stream. As a result, the utilization rate of West German refineries seldom has been as high as 65% of capacity during the past four years.

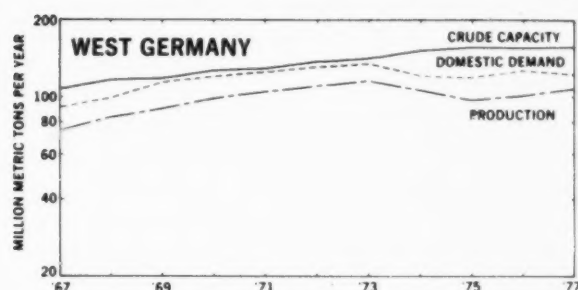


Figure G-1. Trends in West German Domestic Demand, Production, and Crude Capacity

The major role of distillates in West Germany's petroleum economy is shown in Figure G-2, as is the overwhelmingly large share taken by fuel oils as a whole — both distillate and residual. Such heavy demand is rather surprising in view of the governmental measures taken to maintain the once-traditional market for coal and suppress the demand for fuel oils. Those have included special subsidies to lower the price of coal for use at electric-power stations, taxes on both light and heavy fuel oils, and government-requested "voluntary restraint" by refiners on their sales of both types of fuel oil. Because fuel oils constitute such a large portion of the West German market for petroleum products, those measures undoubtedly had a depressant effect on total domestic demand.

Distillate demand in West Germany grew at an average annual rate of almost 13% from 1964 to recession-year 1967, in which it rose less than 2%. In 1968, as shown in Figure G-3, it resumed its rapid growth at a rate of about 12% a year,

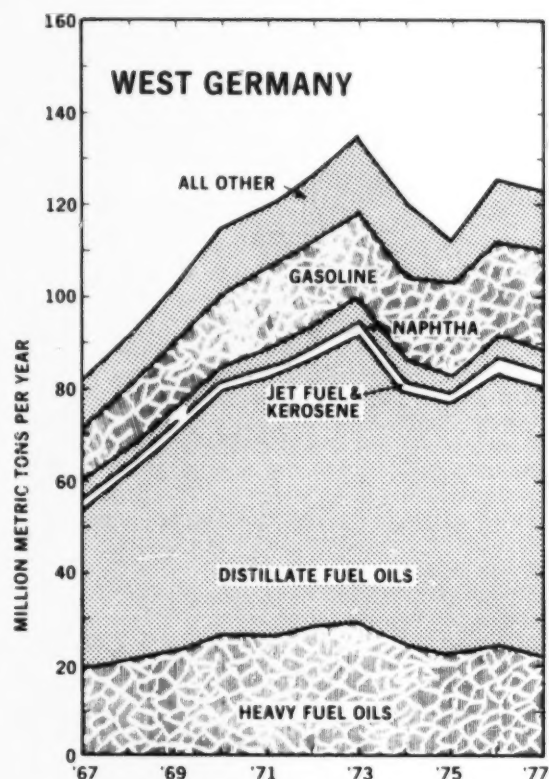


Figure G-2. Distribution of West German Demand Among the Major Products

slowing to 6-7% in 1972 and 1973. In post-embargo 1974 and 1975, it dropped 10.5% and 3.5%, respectively. Since then, it has been erratic, rising 8% in 1976 and declining 2% in 1977.

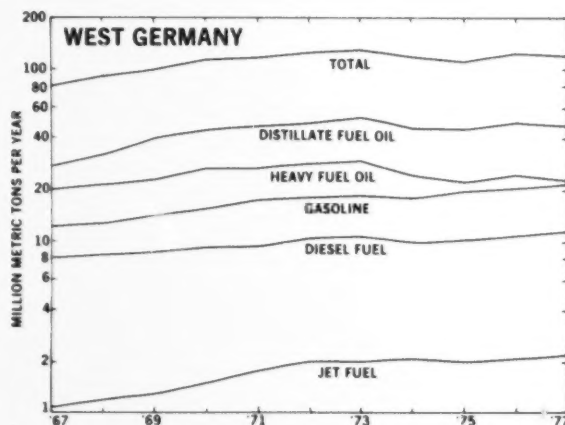


Figure G-3. Rates of Growth in West German Domestic Demand for Major Products

West Germany's demand for heavy fuel oils has been erratic for more than 10 years. Having declined 6% in recession-year 1967, it rose 16% in 1968, 22% in 1969, and 12% in 1970. Then it slowed to 5-8% in 1971-73. Following the oil embargo, it dropped 14% in 1974 and remained flat in 1975. Since it rose 9% in 1976 and dropped 4% in 1977, no new trend is yet apparent.

With gasoline and diesel fuel, however, new trends seemed to have been started in 1975. After a 3% drop in 1974, gasoline demand rose 9% in 1975 – to a level 6% above that in pre-embargo 1973. Since then, it has grown an average 5% per year. Demand for diesel fuel dropped 7% in 1974 but rose 3% in 1975, 6% in 1976, and 7% in 1977.

As shown in Figure G-3, domestic demand for jet fuel grew at a fairly constant annual rate of 12% from 1967 to 1972. Then it flattened out at the 2 million-mT/yr (about 40,000-b/d) level. Since 1975, it has grown 5% annually.

Total domestic demand for petroleum products in West Germany rose an average 9% annually from 1967 through 1973. It then declined for two years, rose in 1976, and slumped somewhat again in 1977. Its 1977 level of about 124 million mT (2.5 million b/d) was 8% below that in 1973.

Outlook for the Future

As shown in Table G-1, West Germany continues to be dependent on oil for more than 50% of its total energy requirement. After the 1973-74 oil embargo, it revised its energy program, calling for a 9% decrease in projected 1985 consumption – to 375 million mT of oil equivalent. The plan would reduce oil's share of the market from the 55% of 1973 to 47% in 1980 and 43% in 1985. Nuclear power's share of the market was to be expanded from the 1% of 1973 to about 8% in 1980 and 16% in 1985.

Nevertheless, petroleum will remain West Germany's major energy source for a long time to come. An early 1978 prediction of domestic demand through 1990 indicated a 21% growth over that period – from about 126 million mT in 1978 to 152 million mT in 1990 (an increase of about 500,000 b/d, to about 3 million b/d in 1990). Table G-2 shows a breakdown of the prediction by major products.

West German gasoline demand will peak in the mid-1980s – at about 24 million mT/yr (560,000 b/d), an Esso AG spokesman predicted early this year. His estimates, shown in Table G-3, take into account the development and use of alternative engines and fuels – including an increase in diesel-powered passenger cars from 4%

TABLE G-1
West German Use of Primary Energy, 1977 vs 1973

Energy Source	Million mT Oil Equiv.			% Change		% Share of Market	
	1973	1974	1977	74/73	77/73	1973	1977
Oil	141.5	127.8	131.9	-9.7	-6.8	55.2	52.1
Coal	57.1	56.2	44.9	-1.6	-21.4	22.2	17.7
Gas	26.2	31.5	37.7	20.2	43.9	10.2	14.9
Lignite	22.4	23.9	24.0	6.5	7.1	8.7	9.5
Nuclear	2.6	2.8	8.0	7.7	207.6	1.0	3.2
Hydro*	5.6	5.0	4.9	-10.7	-12.5	2.2	1.9
Other	1.1	1.1	1.6	0.0	45.5	0.5	0.6
Total	234.1	224.4	253.0	-4.1	8.1	100.0	99.9

*Hydro power includes imported electricity.

TABLE G-2
West German Domestic Demand to 1990

in millions of metric tons

Product	1973	1978	1980	1985	1990
Motor Gasoline	18.5	22.4	22.6	24.0	25.0
Naphtha	5.6	5.4	6.1	8.0	10.0
Diesel Fuel	10.8	12.0	12.3	14.0	16.0
Distillate	52.0	48.0	50.5	52.0	53.0
Residual	29.7	21.5	24.0	24.0	24.0
Other	18.0	16.2	18.7	21.5	24.0
Total	134.6	125.5	134.2	143.5	152.0

Source: Europe Oil-Telegram, 20 April 78, p. 3.

of total West German car population today to 10% in the year 2000.

Over the present 1967-77 survey period, West German motor-vehicle registrations rose 78% – to almost 22 million. The passenger-car population rose 80% – to more than 20 million. As shown in Figure G-4, growth of both car and total registrations rose more rapidly (an average of 8% annually) during the first four years, 1967-71, then slowed to 5% in 1972 and 4% in 1973, before dropping to less than 2% in post-embargo 1974. Since then, they have recorded increasingly larger percentage gains each year – 4.3% in 1975, 5.4% in 1976, and 6.7% in 1977. At a 5% annual

rate of growth, total registrations would reach 25 million in 1980 and passenger-car registrations would reach 23 million. Esso AG's passenger-car forecast in Table G-3 is based on average annual growth rates of about 2% through 1985 and less than 1% thereafter.

As shown in Figure G-5, West Germany's combined cracking and reforming capacity barely exceeds domestic demand. Of the 660,000 b/d (about 28 million mT/yr) of combined capacity in 1977, catalytic reforming accounted for 61%, thermal cracking for 23%, and catalytic cracking for only 16%. Low cracking capacity long has limited West German refiners' ability to produce

TABLE G-3
Development of West German Gasoline Market

Year	No. of Cars millions	Usage km/yr	Consumption litres/100 km	Demand mT/yr
1977	20.0	12,800	11.2	21.8
1980	21.7	12,700	11.2	23.0
1985	23.9	12,400	11.1	24.0
1990	24.8	12,100	10.7	22.9
1995	25.3	12,100	10.7	21.8
2000	25.6	12,000	10.2	20.9

Source: Europe Oil-Telegram, 30 March 78, p. 2

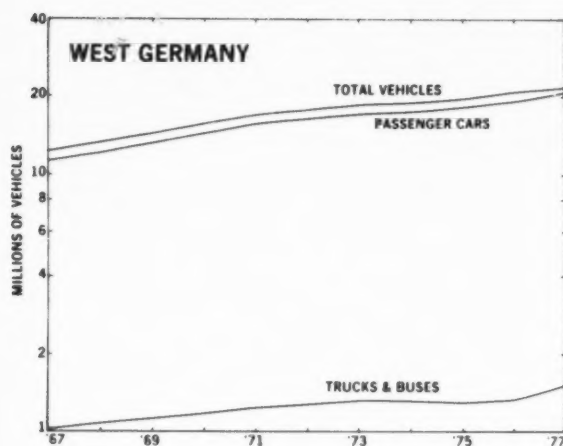


Figure G-4. Rates of Growth in West Germany's Motor-Vehicle Population

desired light products, such as gasoline and petrochemical naphtha, without producing more heavy fuel oil than the market can absorb. This difficulty is reflected in the gap between the Figure G-5 curves for domestic demand and refinery production. In 1976, for example, West Germany's net imports (imports minus exports) of gasoline totaled 3 million mT (about 70,000 b/d), 15% of its total domestic demand.

To alleviate the long-standing problem of low

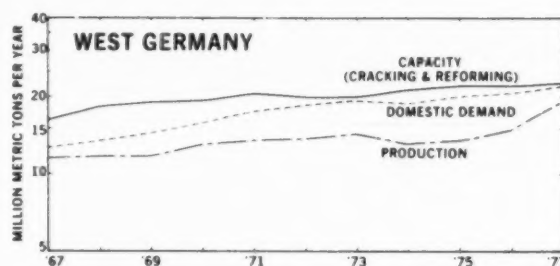


Figure G-5. Growth in West German Gasoline Demand, Output, and Capacity

conversion capacity, West German refiners are adding new catalytic-cracking capacity while holding crude-distillation capacity fairly constant. Projections of West German refining capacity to 1980 by MWV, the refiners' trade association, indicate a 24% increase in cracking capacity will be accompanied by only a 4% increase in crude capacity. Table G-4 summarizes the MWV's projections.

Gasoline Quality

The antiknock quality of West German gasolines was maintained high throughout the survey period. Table G-5 shows the averages of Ethyl S.A. surveys made in the years shown.

TABLE G-4
West German Refining Capacities to 1980

Type of Unit	1976	Capacity, 10 ⁶ mT/yr		1980	% Change 1980 vs 1976
		1977	1978		
Crude Distillation	153.9	154.7	160.3	160.3	4.2
Cat. Cracking	6.6	6.5	9.0	9.5	43.9
Thermal Cracking	3.9	4.1	3.4	3.7	-5.1
Hydrocracking	0.7	1.8	1.8	1.8	157.1
Visbreaking	4.5	4.5	5.8	5.8	28.9
Coking	4.0	3.8	3.7	3.7	-7.5
Total Cracking	19.7	20.7	23.7	24.5	24.4
Crkg/Dist Ratio	12.8%	13.4%	14.8%	15.3%	

Sources: German Oil Information Service, 19 Dec 77, p. 4.
Europe Oil-Telegram, 23 Jan 78, p. 3a.

TABLE G-5
Typical Antiknock Quality of West German Gasolines, 1968-1978

	1968	1970	1972	1974	1976	1978
Premium RON	99.7	98.7	98.5	98.7	98.9	98.5
Premium MON	88.7	88.0	89.6	89.6	88.8	88.8
ΔR_{100}	7.0	10.4	8.1	7.4	7.6	7.7
Pb Content, g/l	0.45	0.52	0.34	0.36	0.18	0.14
% Pb as TML	n.a.	n.a.	n.a.	88	86	43
Regular RON	92.8	92.5	91.9	92.3	92.5	92.5
Regular MON	86.6	86.1	86.1	84.7	84.3	84.6
ΔR_{100}	9.3	13.2	10.4	9.9	8.1	6.2
Pb Content, g/l	0.44	0.42	0.30	0.36	0.14	0.13
% Pb as TML	n.a.	n.a.	n.a.	47	40	15

UNITED KINGDOM

Current Situation

At the beginning of 1964, the United Kingdom was the Eastern Hemisphere's largest consumer of petroleum products (ex the U.S.S.R.), using about 62 million mT/yr, compared with 54 million for Japan and 52 million for West Germany. However, the U.K.'s growth in domestic demand since then has been much slower than that in Japan and West Germany. From year-end 1953 to year-end 1965, U.K. demand grew at an annual rate of about 10%, compared with 25% for Japan and 23% for West Germany. During the next five years, annual growth in U.K. demand averaged 7%, then dropped to less than 1% in 1971, recovered to almost 7% in 1972, and dropped again in 1973 to 2%.

In post-embargo 1974, U.K. demand dropped 6%, and the decline continued with decreases of 13% in 1975 and 6% in 1976. Last year, it showed a modest 2% increase.

As can be seen from Figure UK-1, refinery production closely follows domestic demand. While forced to import its crude oil, the nation is self-sufficient in refining capacity.

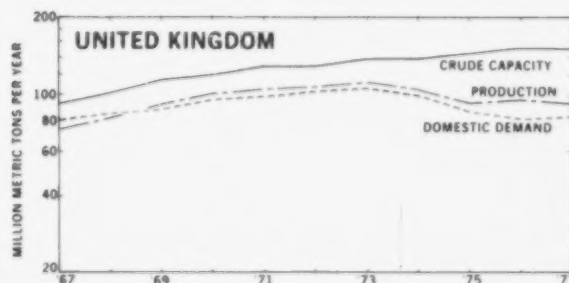


Figure UK-1. Trends in United Kingdom Domestic Demand, Production, and Crude Capacity

As noted in our 1967 survey, gasoline's share of the U.K. petroleum-products market declined from 30% in 1956 to 16% in 1966, during which period growth in gasoline demand averaged about 4% annually. From year-end 1966 to year-end 1973, it averaged almost 6%. However, at the end of that time, gasoline still accounted for only 16% of the U.K.'s total demand for petroleum products – and the same was true in 1974. In 1974, heavy fuel oils accounted for 37% of total U.K. petroleum-product consumption, distillates for 19%, kerosene and jet fuel for 7%, and naphtha for 8% (see Figure UK-2).

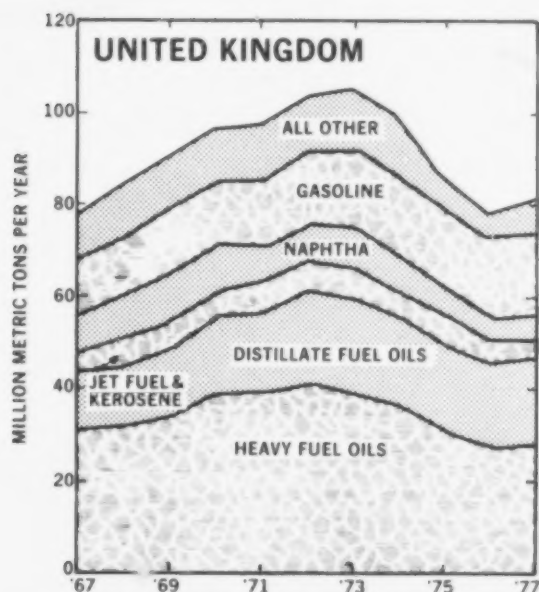


Figure UK-2. Distribution of United Kingdom Domestic Demand Among the Major Products

Since 1974, gasoline is the only petroleum product to show any growth in U.K. domestic demand. Its 1977 demand was 2.4% higher than that in 1974. By contrast, 1977 demand was down 40% for petrochemical naphtha, 36% for jet fuel and kerosene, 3% for distillate fuel oils, and 21% for residual fuel oils, compared with demand in 1974. In 1977, residual fuels accounted for 34.5% of total demand, distillate fuels for 24.3%, gasoline for 21.5%, naphtha for 6.2%, jet fuel and kerosene for 5.3%, and other products for the remaining 8.2%.

As can be seen from Figure UK-3, naphtha for petrochemicals was the most rapidly growing U.K. petroleum product, advancing at an average compound annual rate of 20% from year-end 1964 to year-end 1969. However, naphtha demand dropped at a 17-18% rate in 1970-71, before leveling out in 1972 and rising 13% in 1973. It showed an 8% decrease in recession-ridden, high-priced 1974. Since 1974, naphtha demand has continued to decline – 34% in 1975, 5% in 1976, and 4% in 1977.

Demand for distillate fuel oils and demand for heavy fuel oils followed much the same pattern from 1964 through 1974, as shown in Figure UK-3. From year-end 1964 to year-end 1970,

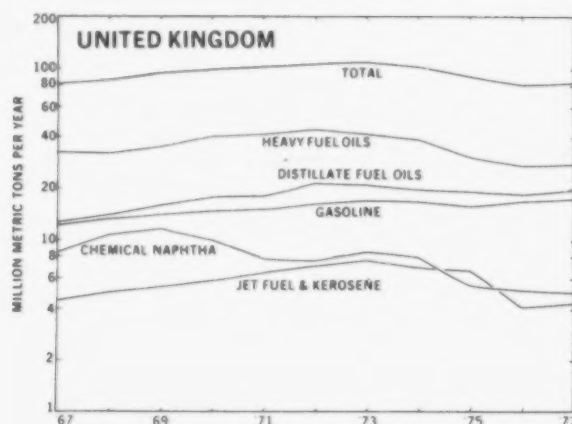


Figure UK-3. Rates of Growth in United Kingdom Domestic Demand for Major Products

combined demand for the two types of fuel oil grew at an average compound annual rate of 8%. From 1971 through 1974, the growth rates were successively 2.4%, 8%, -2.4%, and -6.2%. Since 1974, demand for residual has fallen off markedly. It dropped 18% in 1975 and an additional 9% in 1976, before holding even in 1977. Distillate demand has been much more stable, showing declines of 6% in 1975 and 3% in 1976, followed by a 5% increase in 1977.

Demand for jet fuel and kerosene grew at a quite steady average compound annual rate of 9% from year-end 1964 through year-end 1973. But it dropped almost 13% in 1974. It held steady at the lower level in 1975, then plunged down 39% in 1976. Last year it increased a modest 5%, ending the 1967-77 survey period slightly lower than it was at the beginning.

Outlook for the Future

During the first half of 1978, U.K. domestic demand was up 3% from that in the same period of 1977. As shown in Table UK-1, three major products showed sizeable increases in demand – gasoline almost 7%, jet fuel more than 5%, and heavy fuel almost 5%. However, the trend for petrochemical naphtha continued down, at the 4-5% annual rate of decline shown in 1976 and 1977. Whether increasing availability of North Sea natural gas will further depress U.K. demand for naphtha remains to be seen. Most existing U.K. ethylene plants are designed to use naphtha feedstocks.

TABLE UK-1
U.K. Domestic Demand, January-June 1978

Product	10 ⁶ mT	Demand 10 ³ b/d	% Change from 1977
Gasoline	8.76	408	6.6
Naphtha	2.58	120	-4.9
Jet Fuel	2.07	90	5.1
Kerosene	1.48	64	0.2
Diesel Fuel	2.87	116	1.8
Gas Oil	7.52	305	-0.2
Middle Heating Oil	2.18	89	-4.4
Heavy Heating Oil	12.24	450	4.8
Other	3.54	142	—
Total	43.24	1,784	3.0

Source: Europe Oil-Telegram, 19 Oct 78, p. 7.

In 1975, the U.K.'s national policy of stressing use of coal for power generation, with aid from sharply increased prices for petroleum and its products, reversed a five-year trend of increasing dependence on oil. As shown in Table UK-2, the combined effects of policy and price led to a further decrease in use of oil and increasing reliance on coal in 1976 and 1977. Since then, those factors have succeeded in holding dependence on coal to its reduced level, but no further cuts were achieved as total energy demand began to increase from its 1975 low.

Like other West European nations dependent on imported oil, the U.K. subsidizes the use of coal. But the U.K. subsidy is very low, compared with those in some of the other EEC nations. For example, that of the U.K. was 0.48 European Units of Account (\$0.58) per metric ton last year, compared with 30.75 EUA (\$36.90) in Belgium, 19.77 EUA (\$23.72) in France, and 3.95 EUA (\$4.74) in West Germany. In the EEC as a whole, coal subsidies averaged 4.35 EUA (\$5.22) per metric ton. Their 1977 total of 1,063 million EUA (about \$1.3 billion) was up 44% from 1976.

TABLE UK-2
Energy Consumption in the United Kingdom

Source	Million Metric Tons of Oil Equiv.				1977	% Change 1977 vs 1973
	1973	1974	1975	1976		
Oil	119	114	95	95	95	-20
Coal	78	69	71	72	72	-8
Gas	26	31	33	35	37	42
Other	7	8	8	9	10	43
Total	230	222	207	211	214	-7

*Nuclear and hydro.

Source: Petroleum Economist, Aug 78, p. 339

As can be seen from Figure UK-1, the nation's crude-distillation capacity has reached 150 million mT/yr at a time when demand has shrunk to little over 80 million mT/yr. Following domestic demand, refinery production is down to about 90 million mT/yr. Thus, there is little incentive for near-future expansion of distillation capacity.

However, the U.K.'s Energy Ministry has predicted that the nation will become self-sufficient in energy supply quite soon, perhaps as early as 1980, as the result of its North Sea oil and gas fields. As early as 1975, the Ministry announced intent that most of the oil recovered from the British Sector of the North Sea will be refined in the U.K. The Ministry's avowed high "value added" policy, its efforts to encourage use of coal instead of oil for power generation, and the continuing strong demand for gasoline all suggest that near-future refinery projects will emphasize greater catalytic-cracking capacity, in order to provide high-value light ends.

The beginning of that trend is apparent in Table UK-3, which shows refinery projects underway or planned as of mid-1978. A look at the six expansion projects planned or underway at exist-

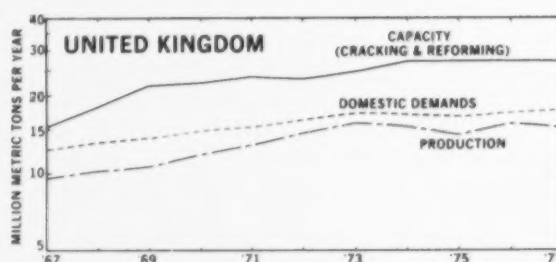


Figure UK-4. Growth in United Kingdom Gasoline Demand, Output, and Capacity

ing refineries reveals that the 13.5 million mT/yr of distillation capacity to be added will be accompanied by 8.8 million mT/yr of catalytic-cracking capacity - a very high ratio, indeed, compared with that traditional in Western Europe.

As shown in Figure UK-4, the U.K. currently has more than enough (27 million mT/yr) of combined reforming and cracking capacity to meet present gasoline demand (about 15 million mT/yr). However, that capacity is 70% reforming and only 30% cracking. Thus, it appears that most new grassroots refineries and most future refinery expansions will include catalytic crackers.

TABLE UK-3

U.K. Refinery Projects Underway or Planned

Company	Refinery	Capacities, mT/yr		Status
		Distillation	Cracking	
Burmah Total	6.0			Planned
Cromarty	10.0			Planned
United	4.0			Planned
Amoco		2.5	1.6	Planned (1981)
Gulf		2.0		Planned
Lindsey		3.0	1.3	Underway (1979)
Mobil		2.5	1.9	Underway (1979)
Pembroke		3.5	3.3	Underway (1979)
Shell			0.7*	Underway (1978)
Total	20.0	13.5	8.8	

*Hydrocracking

Source: Hydrocarbon Processing World-Wide

HPI Construction Boxscore, June 78.

TABLE UK-4
Gasoline Losses from Reducing Lead Content
 (when producing 98-RON premium and 90-RON regular)

Phase	Decrease in Lead Content*		Gasoline Loss % by volume
	grams per liter	g/U.S. gal	
Step 1	From 0.84 to 0.64	From 3.18 to 2.42	2-3
Step 2	From 0.64 to 0.55	From 2.42 to 2.08	1-2
Step 3	From 0.55 to 0.45	From 2.08 to 1.70	2
Step 4			2
Premium	From 0.45 to 0.40	From 1.70 to 1.51	
Regular	From 0.45 to 0.15	From 1.70 to 0.57	
Total losses, Steps 1 through 4			7-9†

*Maximum permissible lead level is same for both grades until Step 4.

†Does not include an additional 0.5% loss resulting from the increased processing energy required at the Step 3 and Step 4 levels.

Gasoline Quality

Because of the energy-conserving value of lead antiknocks, the U.K. has resisted pressures to drastically curtail their use in gasoline, as was done in Japan and West Germany. In 1975, the British Technical Council of the Motor and Petroleum Industries reported the results of a study aimed at investigating "the possibility that . . . a general move in specification level would allow significantly greater efficiency in motor gasoline production . . . and that a case existed for vehicle design modifications to accommodate these 'new' gasolines." The Council found that: "With regard to gasoline volatility there is no unambiguous pressure to move specification levels either up or down and, hence, no case can be made for suggesting vehicle design modifications" (as affects volatility tolerance). Observing that "The efficiency of an engine can be increased by increasing the compression ratio, but this requires improved antiknock quality of the gasoline," the study concluded that:

1. "Gasoline economy in use is most effectively improved by increase in octane quality," and
2. "The most economic means of effecting this lies in the use of lead antiknock compounds."

Assuming, in all cases, production of the same two grades of gasoline (a 98-RON/87-MON premium and a 90-RON regular), the study investigated the percentage losses in total United Kingdom gasoline production that would result from four stepwise reductions in lead content, as shown in Table UK-4. The effects of engine compression ratio on energy-conversion efficiency and fuel economy were shown in the Council's report by curves depicting percentage improvement in power and in fuel consumption as compression ratio is increased. Since the curves are practically straight lines, the report's data are

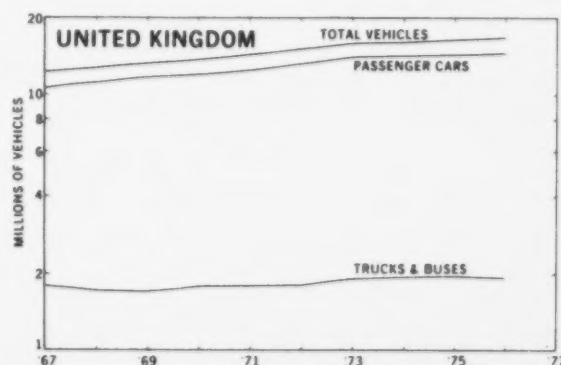


Figure UK-5. Rates of Growth in United Kingdom's Motor-Vehicle Population

TABLE UK-5
Effects of Compression Ratio on Power and Fuel Economy

(percentage improvement in going from baseline 7.5 CR)

Compression Ratio	Improvement over that at 7.5 CR	
	Power, %	Fuel Economy, %
8.0	3	2
8.5	6	4
9.0	8	6

reproduced here in tabular form (Table UK-5) for the sake of printing convenience.

For many years, premium-grade fuel accounted for three-quarters or more of all motor-gasoline sales in the United Kingdom. Regular-grade gasolines were used primarily by trucks, motorcycles, and older cars of lower octane-number requirement. As a result, from 1954 through 1962, the average antiknock quality of British regulars never rose above 85 RON. However, it was increased to about 89 RON in 1963 and, by the end of 1966, it was up to about 91.5 RON. Even with this increase in regular-grade antiknock

quality, premium grades took 77.5% of the U.K. gasoline market in 1966. To accommodate the wide range of octane-number requirement that exists in the U.K., a four-grade system was introduced late in the 1960's. In this system, "Five Star" is a super-premium grade rating 100 RON or more and about 92 MON; "Four Star" corresponds to the old premium grade; "Three Star" is a super-regular; and "Two Star" corresponds to the old regular. As shown in Table UK-6, the antiknock quality and lead contents of the three larger-consumption grades have not changed much since inauguration of the four-grade system.

TABLE UK-6
Typical Antiknock Quality of United Kingdom Gasolines, 1968-1978

	1968	1970	1972	1974	1976	1978
"Four Star" RON	98.3	99.5	98.7	98.3	Ethyl S.A.'s 1976 surveys did not include the U.K.	98.3
"Four Star" MON	89.0	89.9	90.7	90.4		89.9
ΔR_{100}	8.4	7.4	7.0	11.8		9.3
Pb Content, g/l	0.63	0.62	0.57	0.53		0.41
% Pb as TML	n.a.	n.a.	n.a.	62		68
"Three Star" RON	—	95.7	95.5	94.9		94.5
"Three Star" MON	—	86.7	87.9	87.1		87.4
ΔR_{100}	—	8.5	8.8	11.0		9.8
Pb Content, g/l	—	0.53	0.45	0.51		0.37
% Pb as TML	—	n.a.	n.a.	33		59
"Two Star" RON	91.4	91.6	91.8	91.0		90.9
"Two Star" MON	84.3	84.6	86.5	84.9		85.0
ΔR_{100}	8.8	9.3	9.2	10.6		9.8
Pb Content, g/l	0.42	0.47	0.49	0.50		0.39
% Pb as TML	n.a.	n.a.	n.a.	6		49

ITALY

Current Situation

Among the major Eastern Hemisphere refining nations, Italy is the only large-scale exporter of petroleum products. In recent years, it has exported about 16% of its refinery output – down from 25% in 1973 and 20% in 1974. Large-scale exports, plus the fact that the government requires refiners to maintain 30% reserve capacity, account for Italy's having almost 200 million mT/yr of crude-distillation capacity in pre-embargo 1973, despite a domestic demand of only about 110 million mT/yr. Since then, as shown in Figure I-1, capacity has been increased only 8%, but domestic demand has dropped 24%. As a result, Italy's utilization of refining capacity in 1977 was only 49%, lowest in the EEC nations.

Residual fuel has dominated Italy's domestic-demand pattern for many years. In 1956, it accounted for 65% of the total demand for petroleum products. At the beginning of the present survey, in 1967, it accounted for 58% (see Figure I-2). Ten years later, in 1977, residual's share of the petroleum-product market was down to 42%.

The product that has been cutting residual's share the most is distillate, as can be seen from both Figure I-2 and Figure I-3. Over a nine-year period ending in 1973, Italian demand for distillate quadrupled, compared with only a 1.6-fold increase in demand for residual. During that period, distillate's share of the domestic market

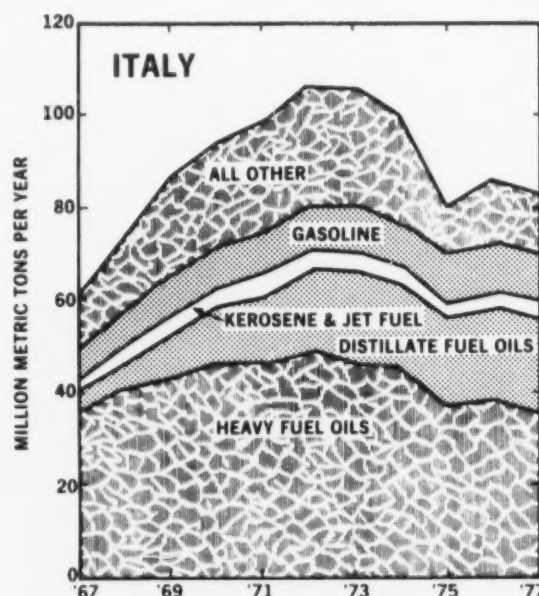


Figure I-2. Distribution of Italian Domestic Demand Among the Major Products

rose from 10% to 18%. During the four-year period 1969-73, distillate demand grew at an average compound annual rate of 10%. Following a post-embargo dip in 1974, it resumed its growth at an average annual rate of 9%.

Gasoline demand increased over the nine-year pre-embargo period 1964-73 at a relatively steady average annual rate of almost 8%. Since then, it has remained near the 1973 level, vacillating slightly from year to year.

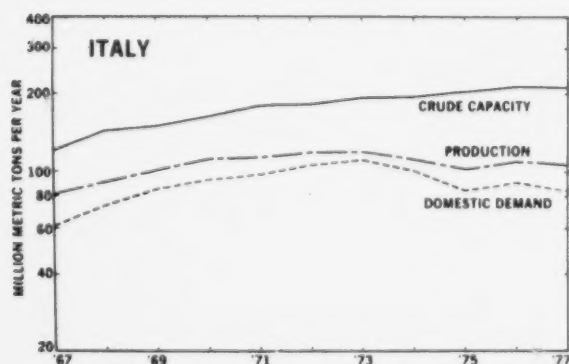


Figure I-1. Trends in Italian Domestic Demand, Production, and Crude Capacity

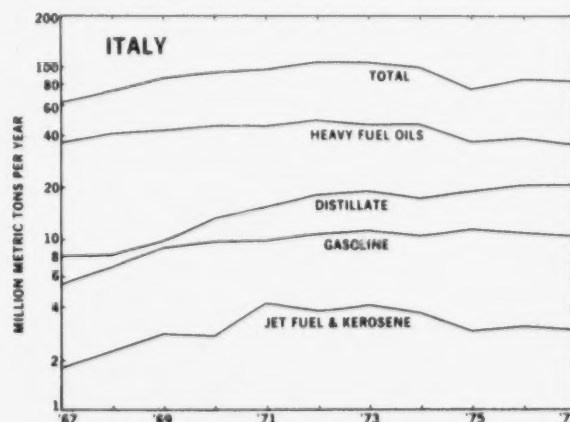


Figure I-3. Rates of Growth in Italian Domestic Demand for Major Products

As shown in Figure I-3, demand for heavy fuel oils and for jet fuel and kerosene peaked in the 1971-73 period and ended the survey period down 17% and 27%, respectively. Total domestic demand also peaked in the 1972-73 period, ending the survey period down 20% from its peak and up only 35% over that in 1967. In effect, total Italian domestic demand ended the survey period no higher than it would have at a steady average growth rate of 3% a year.

Outlook for the Future

Unless Italy can develop indigenous supplies of crude oil, as the United Kingdom and some of the other EEC countries have, its chances of expanding its refining industry at pre-1974 rates seem quite small. Logically, a nation that does not produce crude oil probably cannot compete favorably in the export market as long as crude-oil prices are controlled by a producers' cartel.

Future growth of the Italian petroleum-refining industry will, therefore, be conditioned almost entirely by growth in domestic demand. Early in 1978, the nation announced a revised energy plan based on assumption that demand from all sources will total 167 million mT (about 3.3 million b/d) of oil equivalent in 1980 and 206 million mT (about 4.1 million b/d) of oil equivalent in 1985. As can be seen from Table I-1, the plan calls for oil to supply at least 65% of Italy's total energy consumption through 1985. Nuclear energy is expected to supply less than 5% of the total, even by 1985. And all other sources are expected to be able to supply only about 30% of the total.

With Italian domestic demand at an 84 million mT-yr level in 1977, the new Italian plan

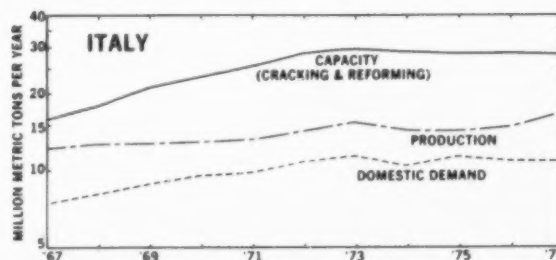


Figure I-4. Growth in Italian Gasoline Demand, Output, and Capacity

would require average annual growth rates of 11% over the 1978-80 period and only 3% thereafter. Apparently, the planners believe that 1977's 2% decline in domestic demand was a temporary slump that will be compensated for during the remaining years of the 1975-80 period. Actually, a straight trend line drawn from the 1975 data point on the total-demand curve of Figure I-3 through the 1977 data point and extended to 1980 comes fairly close (101 million mT/yr) to the 1980 level forecast in the plan and very close (136 million mT/yr) to that forecast for 1985. The line represents growth at a constant average annual rate of 6%.

Since gasoline and distillate fuels already have recovered strongly from the post-embargo slump in petroleum-product demand, future Italian refinery expansion and upgrading projects may be expected to include catalytic crackers. As shown in Figure I-4, Italy's combined cracking and reforming capacity is far ahead of recent demand. However, the majority (60%) of that capacity is reforming, which requires running more crude to produce additional gasoline. That, of course,

TABLE I-1
Oil's Place in Italy's Revised Energy Plan

Source	Million mT of Oil Equiv.		% Share of Total	
	1980	1985	1980	1985
Oil	114.6	134.1	68.6	65.1
Nuclear	1.6	10.1	1.0	4.9
All Other	50.8	61.8	30.4	30.0
Total	167.0	206.0	100.0	100.0

produces more heavy fuel oil, whose share of the market has been decreasing.

Gasoline Quality

In Italy, the government sets minimum fuel-quality specifications, based on the recommendations of a committee (CUNA) composed of engine makers, gasoline producers, and government representatives. Actual gasoline quality averages somewhat above those minimum specifications, the level being set by competitive influences. In general, Italian regulars are designed to just satisfy the more popular small cars. Thus, as pointed out by G. B. Cipollina of Mobil Oil Italiana at the Fifth World Petroleum Congress (Section VI, Paper 7), "Car manufacturers take full advantage of available gasoline... (and) regular gasoline is borderline with regard to vehicle requirements."

In 1964, when regulars averaged about 86 RON and 82 MON, they were estimated to satisfy about 50% of the Italian passenger-car population and essentially all of its rather small truck population. At their 1966 level of about 87 RON and 83.5 MON, regulars accounted for 40% of total gasoline sales. In our 1967 survey, we predicted that premium fuels would take about 62% of the Italian motor-gasoline market. The then-observed trend toward premium gasoline has accelerated in recent years. By 1975, premium grade accounted for 90% of all motor gasoline sold in Italy. During the first ten months of 1968, premium's share averaged 94%.

The Research rating of Italian premium-grade gasolines has not changed appreciably since 1959.

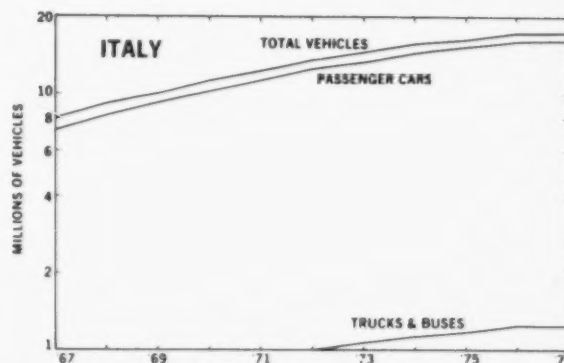


Figure I-5. Rates of Growth in Italy's Motor-Vehicle Population

However, their overall antiknock quality has been improved considerably, largely from use of TML (tetramethyllead) antiknocks. While their aromatic content (30-35%) and olefin content (6-8%) have remained practically the same, their sensitivity (RON-MON) decreased from 10.5-11 as late as 1964 to only 6.5 in 1974 – when 73% of the lead used in Italian premiums was TML (see Table I-2). As might be expected, the 1974 Italian premiums had as low ΔR_{100} (7.1 compared with 8.9 in 1966). A mid-1977 survey of Milan gasoline_s showed them using slightly less total lead (0.55 vs 0.60 g/litre) and a somewhat lower percentage of TML (60% vs 73%) than the 1974 premiums. Predictably, they were somewhat inferior to the 1974 premiums in sensitivity (7.9 vs 6.5) and ΔR_{100} (9.8 vs 7.1).

As shown in Figure I-5, the Italian motor-vehicle population consists almost exclusively (93%) of passenger cars. The growth trends graphed in that figure indicate that passenger-car octane requirements will continue to determine gasoline octane levels and premium-to-regular ratios in the foreseeable future.

TABLE I-2
Typical Antiknock Quality of Italian Gasolines, 1968-1978

	1968	1970	1972	1974	1976	1978
Premium RON	99.0	98.7	98.5	98.6	98.4	98.3
Premium MON	89.6	91.1	90.7	92.1	89.9	90.4
ΔR_{100}	8.4	9.3	8.5	7.1	10.0	9.8
Pb Content, g/l	0.60	0.62	0.55	0.60	0.64	0.55
% Pb as TML	n.a.	n.a.	n.a.	73	56	60
Regular RON	86.4	86.0	86.8	85.4	85.2	85.8
Regular MON	80.8	81.5	82.7	81.4	82.4	83.2
ΔR_{100}	11.8	12.6	11.6	8.8	11.8	10.5
Pb Content, g/l	0.45	0.48	0.41	0.39	0.42	0.34
% Pb as TML	n.a.	n.a.	n.a.	10	16	15

FRANCE

Current Situation

For many years, French domestic demand for petroleum products has shown the relatively slow rate of growth characteristic of a nation having a long-established and moderately expanding industrial economy. During the 1956-66 period of our previous survey, French domestic demand only tripled, compared with a nine-fold increase in Japan, a more than six-fold increase in West Germany, and a five-fold increase in Italy. From year-end 1964 to year-end 1973, it increased at an average compound annual rate of 11.6%, which would have seen it exactly tripling again – from 41.6 million metric tons in 1964 to 124.7 million in 1974. But, although such growth occurred on schedule through 1973, demand dropped in 1974 to only 104.5 million metric tons. (So, farewell to one of the longest, most predictable trends we have ever encountered.)

Since 1974, French domestic demand has vacillated narrowly above and below the 100 million-mT/yr level. Specifically, it sagged to 95.8 million mT in 1975, recovered to 103.8 million mT in 1976, and dropped again in 1977 to 98.8 million mT.

Under a national policy that favors home refining over importing, French crude capacity normally is expanded at about the same rate that domestic demand is increasing. That is evident from the 1967-73 segment of the crude-capacity curve.

Also evident – from the production and demand curves in Figure F-1 – is the fact that refinery output consistently exceeds domestic demand. For years, France has been exporting 10-15% of the products its refineries produce. Of the 340,000 b/d (about 17 million mT/yr) of refined products that France exported in 1976,

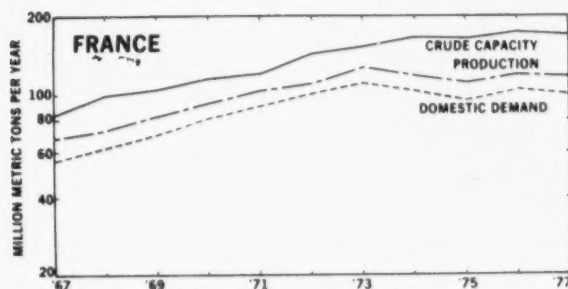


Figure F-1. Trends in French Domestic Demand, Production, and Crude Capacity

gasoline accounted for 13%, jet fuel and kerosene for 9%, distillate fuels for 26%, residual fuel oils for 32%, lubricants for 3%, and other products for the remaining 17%.

As shown in Figure F-2, fuel oils – distillate and residual – account for a very high percentage of total French domestic demand. Until the 1973-74 quadrupling of prices for imported crude oil, distillates and residuals accounted for 70-75% of French domestic demand. In the 1975-77 period, their share declined annually – from 68% in 1975 to 67% in 1976 and 66% in 1977. From year-end 1964 to year-end 1972, distillate's share of total domestic demand rose from 40% to 42%, and that of residual rose from 26% to 30%. Over

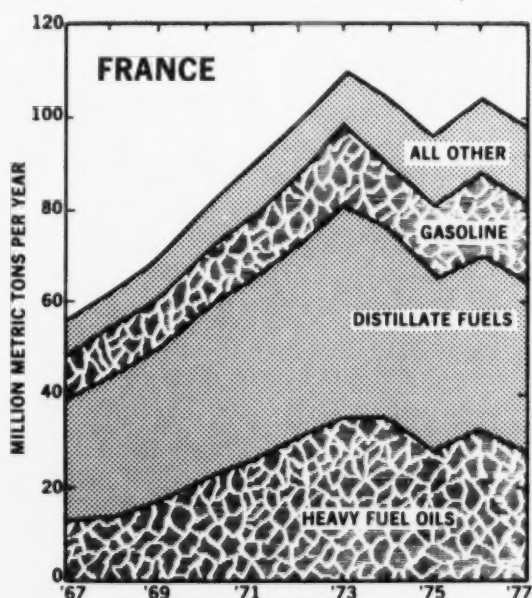


Figure F-2. Distribution of French Demand Among the Major Products

the same period, gasoline's share shrank from 18.5% to 14.6%. With distillate demand showing a 13% decrease in 1974, gasoline a 4% decrease, and residual a 1% increase, the market shares shifted to 14.5% for gasoline, 38% for distillate, and 33% for residual.

Since 1974, gasoline's share of the market has been 16-17%. Distillates have accounted for 37-38% of the total market. And residual has taken a 28-31% share.

As shown in Figure F-3, distillate demand grew quite uniformly from 1967 through 1973 at an average annual rate of 11%. It then dropped sharply for two years and flattened at the lower level for the final two years of the survey period.

Demand for heavy fuel oils rose even faster than that for distillates prior to 1973. From 1968 to 1973, the growth rate averaged 21% per year. Heavy-fuel demand also slumped after 1973, as can be seen in Figure F-3.

Only gasoline has shown consistent growth since 1973. During the first six years of the survey period, its demand grew an average 8% per year. After a flat 1974, gasoline demand resumed its growth at about 5% a year.

Outlook for the Future

During the first six months of 1978, French domestic demand for petroleum products was up 5.9% from that in the same period of 1977.

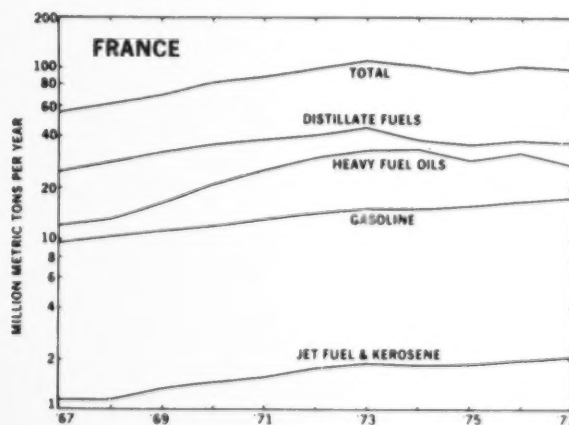


Figure F-3. Rates of Growth in French Domestic Demand for Major Products

Gasoline demand was up 5.2%, with the super grade accounting for 82% of total sales.

Announced French goals for meeting the nation's 1985 energy requirement call for a 23% decrease in use of oil for producing electricity, with nuclear energy providing more and more of the nation's electrical power. The French petroleum institute (IFP) foresees a West European trend away from the heavy end of the crude barrel to lighter higher-value products.

As shown in Figure F-4, French catalytic cracking and reforming capacity was not increased appreciably from 1973 through 1977. At the end of the survey, France had about 28 million mT/yr (650,000 b/d) of combined cracking and reforming capacity. But catalytic cracking accounted for only about 26% of the total. In line with IFP's predicted West European trend toward lighter products, catalytic crackers can be expected to play an increasingly larger role in French refining.

As shown in Figure F-5, the French motor-vehicle population has grown at remarkably consistent rates over the survey period. From 1967 through 1973, the growth rate was 5-6% annually. Since 1973, the rate has been closer to 4% a year.

Gasoline Quality

So that French passenger cars could compete favorably with foreign makes in both performance and fuel economy, the Government Technical Services established a planned series of compression-ratio increases beginning in 1958. To

permit those increases and to allow a greater portion of the car population to be operated on regular-grade fuels, the agency also specified a series of planned increases in antiknock quality of both grades, with a reduction of the difference between them. The plan called for five annual upgradings to raise regulars from the 1958 level of 80 RON to 90 RON by the end of 1962 and premiums from 90 RON to 98 RON over the same period. As a result of that plan, the average compression ratio of French cars was raised more than 1.0 CR, and some 60% of the new-car population could be satisfied by regular-grade fuels.

As can be seen in Table F-1, the antiknock quality of French gasolines has not changed much since the upgrading plan reached its goal. Apparently the regular grade's 90-RON / 84-MON antiknock quality is not high enough for most cars now operated in France, since 82% of the motor gasoline consumed in France during the first half of 1978 was premium grade. As a result of their relatively high content of heavy aromatics from catalytic reforming and very low content of light olefins from catalytic cracking, French gasolines tend to have quite poor frontend antiknock quality; i.e., high ΔR_{100} . Substituting more TML or one of the lighter mixed lead alkyls for TEL would be expected to improve road antiknock performance at low engine speeds.

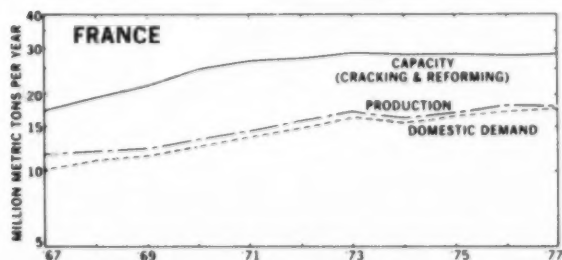


Figure F-4. Growth in French Gasoline Demand, Output, and Capacity

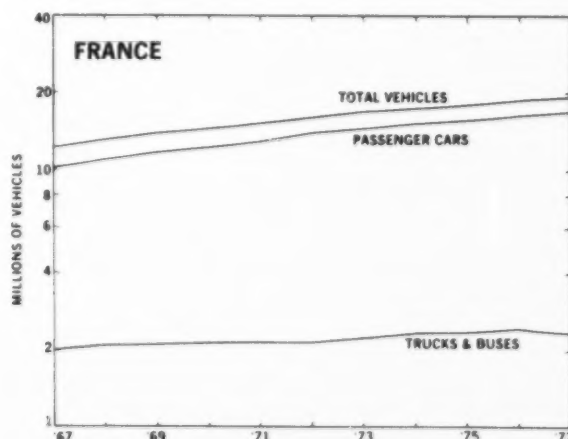


Figure F-5. Rates of Growth in France's Motor-Vehicle Population

TABLE F-1
Typical Antiknock Quality of French Gasolines, 1968-1978

	1968	1970	1972	1974	1976	1978
Premium RON	98.2	98.7	98.3	97.9	97.7	97.6
Premium MON	88.0	87.7	88.5	88.8	88.4	88.7
ΔR_{100}	9.0	9.2	10.8	11.4	10.2	9.9
Pb Content, g/l	0.49	0.41	0.51	0.60	0.50	0.55
% Pb as TML	n.a.	n.a.	n.a.	22	35	25
Regular RON	90.1	90.9	90.7	90.5	90.4	90.1
Regular MON	84.4	85.1	84.1	83.6	83.9	84.1
ΔR_{100}	12.6	9.6	11.0	10.1	11.2	12.3
Pb Content, g/l	0.56	0.34	0.41	0.46	0.48	0.53
% Pb as TML	n.a.	n.a.	n.a.	2	17	8

ELSEWHERE IN EUROPE

Current Situation

As shown in Table E-1, the other petroleum-refining nations of Europe range in crude-distillation capacity from the Netherlands' 93.5 million mT/yr down to Switzerland's 6.9 million. Many of the countries have little or no catalytic cracking. Some, like the Netherlands and Belgium, export as much as half of their total refinery production – which accounts for their large distillation capacities relative to their levels of domestic demand.

As shown in Figure E-1, demand grew very rapidly throughout the survey period in Spain, Yugoslavia, and Turkey. From 1967 through

1976, Spanish demand grew at an average rate of 10% per year, then declined slightly in 1977. Yugoslavia's demand grew even faster, at almost 12% a year. And Turkish demand almost tripled – from about 5.2 million mT/yr in 1967 to 16.5 million in 1977.

Greek domestic demand rose at a 16% annual rate from 1970 through 1973, but flattened after the oil embargo and sharply higher crude-oil prices.

In Belgium, the Netherlands, and Switzerland, demand grew reasonably steadily through 1973, but slumped thereafter. Portugal's demand, on the other hand, rose steadily from 1973 through 1976, but sagged a bit in 1977.

TABLE E-1
European Refining Capacities

Million Metric Tons per Year as of Jan. 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
Netherlands	93.5	38.6	7.8	3.2	3.4
Spain	63.6	17.6	6.7	—	—
Belgium	53.4	23.5	5.6	3.0	5.6
Portugal	20.8	6.6	2.3	0.5	2.4
Greece	20.4	5.0	0.9	—	—
Turkey	16.3	3.9	1.2	1.8	11.0
Yugoslavia	14.7	2.2	2.0	0.1	0.6
Austria	14.0	2.7	1.0	0.7	5.0
Switzerland	6.9	3.9	1.2	—	—

To avoid a confusing multiplicity of trend lines on a single chart, the Scandinavian group of nations has been separately graphed in Figure E-2. As can be seen, their domestic demand has been flat since the early 1970s. Before then, growth was quite rapid. From year-end 1964 to year-end 1973, domestic demand for petroleum products more than doubled in all of the Scandinavian nations except Sweden, the largest consumer of the group. In Denmark, the second largest, demand grew 2.1-fold, from 8.3 million mT/yr to 17.5 million. In Finland, the growth was 2.8-fold, from 4.4 million to 12.2 million. And in Norway, it was 2.1-fold, from 4.2 million to 9 million. All of the Scandinavian nations suffered demand losses in 1974 - about 7% in Sweden, 15% in Denmark, and 10% in both Finland and Norway.

Sweden, Finland, and Denmark are net importers of petroleum products. In 1976, Sweden imported almost 58% of the refined products it consumed; Denmark, 66%; and Finland, 22%. Norway is nearly self-sufficient in refining capacity, being a net importer of only 4 million mT of refined products in 1976. Table E-2 shows Scandinavian refining capacities. To date, catalytic cracking is almost nonexistent in the area.

Outlook for the Future

Figures E-3 and E-4 show the growth of motor-vehicles in the various European countries during the present survey period. Those nations in which registrations have been growing most

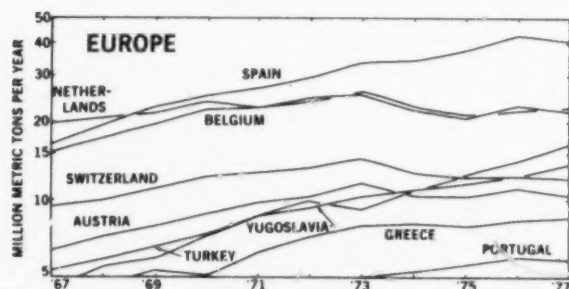


Figure E-1. Trends in Total Domestic Demand in Various European Nations

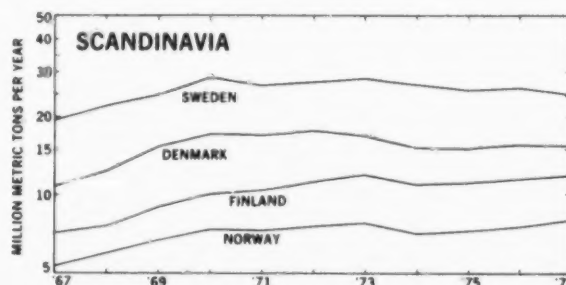


Figure E-2. Trends in Total Domestic Demand in the Scandinavian Nations

TABLE E-2
Scandinavian Refining Capacities

Million Metric Tons per Year as of Jan. 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
Sweden	21.2	4.6	3.3	—	None
Finland	16.8	8.6	2.4	0.4	2.4
Norway	13.2	2.5	1.3	—	None
Denmark	11.0	4.3	1.6	—	None

rapidly would, of course, be expected to show the strongest growth in gasoline demand in the near future. In some cases, the passenger cars being added in those nations are the first their owners

have ever had — and a large unfilled demand still exists.

Gasoline Quality

As can be seen from Table E-3, all of the European refining nations now produce high-octane gasoline. Motorists now should be able to drive practically anywhere on the Continent without encountering octane-requirement problems.

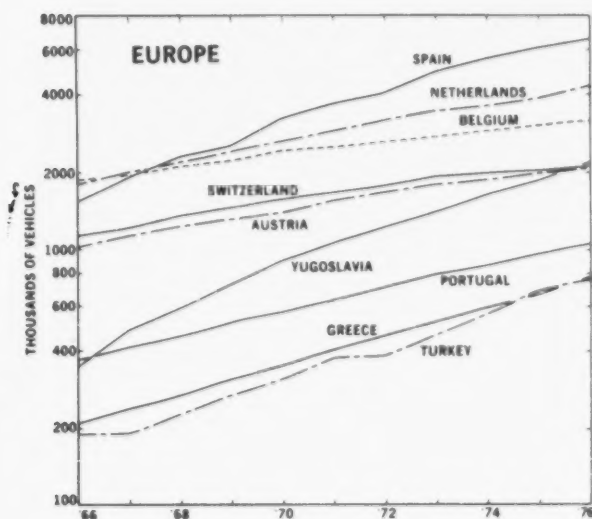


Figure E-3. Rates of Growth in European Motor-Vehicle Population

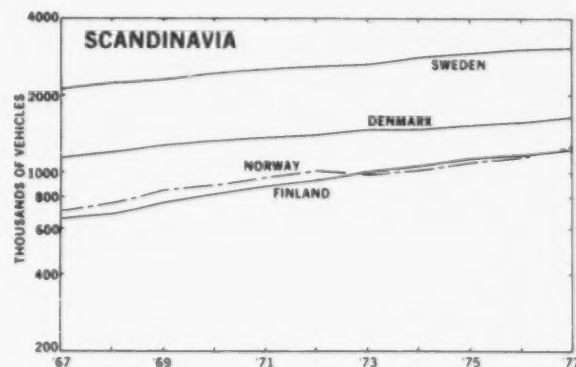


Figure E-4. Rates of Growth in Scandinavian Motor-Vehicle Population

TABLE E-3
Typical Antiknock Quality of European Gasolines

Nation	1968	1970	1972	1974	1976	1978
Austria						
Premium RON	97.2	98.1	98.2	97.5	98.0	98.0
Premium MON	87.8	87.3	88.7	88.0	89.0	88.4
Pb in Prem., g/l	0.44	0.67	0.36	0.36	0.40*	0.33
Regular RON	87.0	87.5	87.7	88.0	88.4	88.4
Regular MON	83.0	81.7	81.6	81.5	82.6	84.0
Pb in Reg., g/l	0.74	0.61	0.30	0.35	0.40*	0.40*
Belgium						
Premium RON	98.2	99.4	99.1	98.7	98.5	98.7
Premium MON	89.0	90.1	90.0	89.0	89.2	89.9
Pb in Prem., g/l	0.65	0.61	0.63	0.59	0.63	0.42
Regular RON	90.6	91.9	92.2	92.2	91.5	91.8
Regular MON	84.5	85.3	85.5	85.0	85.2	85.0
Pb in Reg., g/l	0.42	0.25	0.32	0.44	0.40	0.31
Denmark						
Premium RON	100.2	99.4	99.4	99.4	99.9	99.7
Premium MON	91.0	90.5	91.4	91.0	91.3	91.0
Pb in Prem., g/l	0.74	0.65	0.61	0.63	0.61	0.40*
Premium RON	94.5	94.6	95.7	94.5	93.7	94.1
Regular MON	87.4	86.9	89.0	88.0	87.8	88.1
Pb in Reg., g/l	0.47	0.58	0.42	0.47	0.47	0.40*
Finland						
Premium RON	99.5	99.2	100.3	99.8	99.0	98.0
Premium MON	91.1	88.9	92.3	89.4	89.3	87.0
Pb in Prem., g/l	0.58	0.66	0.45	0.45	0.48	0.37
Regular RON	92.1	92.2	92.2	92.0	92.4	93.4
Regular MON	85.9	86.4	85.2	84.9	86.7	84.8
Pb in Reg., g/l	0.59	0.61	0.52	0.59	0.61	0.26
Greece						
Premium RON	96.3	96.1	97.0	97.0	97.0	97.0
Premium MON	90.7	89.4	87.6	—	—	—
Pb in Prem., g/l	0.83	0.73	0.61	0.72	0.72	0.84*
Regular RON	85.6	84.5	85.9	90.0	90.0	90.0
Regular MON	81.2	82.5	83.2	—	—	—
Pb in Reg., g/l	0.53	0.55	0.68	0.60	0.60	0.84*

Continued on next page

TABLE E-3 (Continued)

	1968	1970	1972	1974	1976	1978
Netherlands						
Premium RON	98.4	98.7	99.3	98.9	98.4	98.8
Premium MON	89.3	90.3	90.9	90.7	90.2	90.7
Pb in Prem., g/l	0.71	0.61	0.51	0.70	0.61	0.32
Regular RON	91.2	92.7	93.7	92.5	92.7	94.1
Regular MON	84.8	86.2	87.4	84.9	86.1	86.1
Pb in Reg., g/l	0.49	0.37	0.31	0.38	0.45	0.32
Norway						
Premium RON	99.8	100.1	100.4	98.8	99.6	99.5
Premium MON	90.8	91.0	91.4	89.0	90.6	92.3
Pb in Prem., g/l	0.51	0.54	0.52	0.53	0.36	0.36
Regular RON	93.1	94.7	93.2	93.3	94.0	94.1
Regular MON	86.0	87.0	86.7	87.4	88.5	88.5
Pb in Reg., g/l	0.40	0.33	0.30	0.43	0.32	0.38
Portugal						
Premium RON	95.3	95.6	96.5	98.6	98.1	98.3
Premium MON	85.6	86.3	87.0	89.5	89.3	88.6
Pb in Prem., g/l	0.63	0.52	0.56	0.59	0.59	0.50
Regular RON	85.7	85.2	85.5	86.6	85.5	85.8
Regular MON	81.4	81.9	78.0	83.1	80.7	81.6
Pb in Reg., g/l	0.44	0.52	0.59	0.54	0.56	0.50
Spain						
Premium RON	98.4	97.8	97.3	98.7	97.8	98.3
Premium MON	88.6	89.3	88.8	89.8	90.5	89.0
Pb in Prem., g/l	0.74	0.74	0.70	0.80	0.61	0.62
Midgrade RON	—	—	95.7	96.4	96.4	96.6
Midgrade MON	—	—	89.7	88.7	89.7	88.2
Pb in Mid., g/l	—	—	0.70	0.72	0.59	0.54
Regular RON	86.0	87.1	85.5	87.0	86.5	90.0
Regular MON	82.0	81.5	80.5	83.0	83.0	85.0
Pb in Reg., g/l	0.31	0.34	0.30	0.36	0.39	0.48*
Sweden						
Premium RON	100.6	100.1	100.4	99.6	99.0	99.0
Premium MON	91.8	91.9	91.0	90.1	90.2	91.3
Pb in Prem., g/l	0.82	0.61	0.40	0.40	0.34	0.34
Regular RON	95.0	96.9	96.5	94.3	94.5	94.2
Regular MON	88.9	88.2	88.3	86.1	87.1	87.8
Pb in Reg., g/l	0.65	0.39	0.36	0.38	0.33	0.26

TABLE E-3 (Continued)

	1968	1970	1972	1974	1976	1978
Switzerland						
Premium RON	98.0	98.5	98.6	97.9	98.7	98.3
Premium MON	90.3	91.3	89.9	90.1	90.2	90.8
Pb in Prem., g/l	0.52	0.58	0.42	0.46	0.37	0.39
Regular RON	90.7	91.5	92.4	91.4	91.7	90.9
Regular MON	85.6	86.6	86.4	85.7	86.0	86.3
Pb in Reg., g/l	0.46	0.46	0.37	0.44	0.38	0.15*
Turkey						
Premium RON	†	94.5	94.5	94.0	95.0	95.0
Premium MON	†	86.5	86.5	86.5	88.0	88.0
Pb in Prem., g/l	†	0.58	0.58	0.58	0.50	0.50
Regular RON	84.5	82.5	82.5	83.5	85.0	85.0
Regular MON	80.0	80.0	80.0	80.0	79.0	79.0
Pb in Reg., g/l	0.42	0.40	0.40	0.42	0.26	0.26
Yugoslavia						
Premium RON	99.2	99.1	99.0	98.0	98.0	98.2
Premium MON	89.2	90.0	88.5	89.0	90.0	90.8
Pb in Prem., g/l	0.69	0.44	0.56	0.70	0.60	0.53
Regular RON	87.2	89.1	87.5	88.5	88.0	86.1
Regular MON	83.4	82.4	83.0	85.0	82.0	82.5
Pb in Reg., g/l	0.73	0.50	0.50	0.60	0.45	0.60*

*Maximum allowable.

†In 1968, Turkey had only one grade of gasoline.

AFRICA

Current Situation

Refining capacity in Africa at the end of 1977 totaled about 74 million mT/yr (1.5 million b/d), in 22 countries. Of that total, the seven nations listed in Table AF-1 account for 58 million mT/yr, or almost 80%. They also account for 74% of Africa's hydrogen-processing capacity, 68% of its catalytic-reforming capacity, and 97% of its catalytic-cracking capacity.

In addition to being the largest refining nations on the African Continent, the seven covered in this survey account for almost three-quarters of the Continent's total demand for petroleum products – which amounted to 54 million mT (about 1.1 million b/d) in 1976. Of the seven nations, only Algeria and Libya are appreciable exporters of refined products. In 1976, Algeria's net exports amounted to 24% of its refinery output. Libya's net exports equaled 45% of its refinery production. Figure AF-1 shows trends of domestic demand in each of the nations.

Outlook for the Future

As can be seen from Figure AF-1, domestic demand has grown at widely varying rates in the individual nations. In Egypt, demand in-

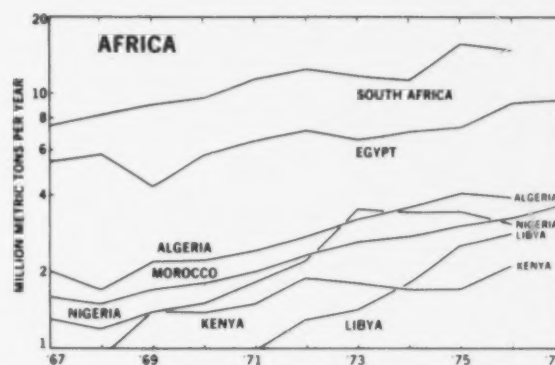


Figure AF-1. Trends in Total Domestic Demand in African Nations

creased only 72% over the entire ten-year survey period, equivalent to an average growth rate of 5-6% a year. That of Libya, on the other hand, practically tripled in the five-year period 1971-76, growing an average 23% per year.

The most consistent demand trend has been that of Morocco from 1968 through 1977. Over that period, its demand more than doubled, growing about 10% a year. Algerian demand showed a quite steady 13% annual growth from 1970 through 1975, but sagged a bit in 1976.

TABLE AF-1

African Refining Capacities

Million Metric Tons per Year as of Jan. 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
South Africa	22.3	7.1	1.8	3.0	13.5
Egypt	11.7	—	0.3	—	—
Libya	6.8	1.9	0.6	—	—
Algeria	6.1	1.2	1.0	—	—
Kenya	4.8	1.6	0.4	—	—
Morocco	3.6	0.4	0.4	—	—
Nigeria*	3.0	—	0.3	—	—

*Nigeria completed a 5 million-mT/yr refinery in 1978. It has 1.3 million mT/yr of catalytic-cracking capacity and about 700,000 mT/yr of naphtha hydrotreating and reforming capacity.

Nigeria and Kenya have had spurts of growth in demand followed by flat periods. However, in both nations, domestic demand more than doubled during the survey period. After languishing at about 6 million mT/yr from 1964 through 1966, South African demand grew at an average compound annual rate of more than 12% through 1972. It declined somewhat in 1973 and 1974, then took a sudden spurt in 1975, only to decline again in 1976. Short crude-oil supply and high prices of imported crude make it unlikely that South African demand will resume expansion at its pre-1973 rate in the foreseeable future. The nation appears to be basing much of its future petroleum-products supply on oil-from-coal plants. The new Sasol No. 2 plant reportedly will be ten times the size of Sasol No. 1. Employing M. W. Kellogg Company's Synthol process, a version of the Fischer-Tropsch process that produces mainly low-boiling hydrocarbon products, the new plant is expected to produce 1.5 million mT/yr of automotive fuels, along with 150,000 mT/yr of ethylene and substantial amounts of other hydrocarbon products, ammonia, sulfur and coal-tar derivatives.

Petroleum-refining growth in the oil-producing nations of Africa – notably Libya, Nigeria, and Algeria – obviously will not be inhibited by lack of crude oil – or its cost elsewhere in the world. Already Africa produces more than 10% of the world's oil. And those three nations – Libya, Nigeria, and Algeria – produce almost 90% of Africa's total. We might, therefore, expect vigorous expansion in each of those countries.

Nigeria completed its second refinery in mid-1978, raising its crude-distillation capacity from 3 million mT/yr to 8 million mT/yr (about 160,000 b/d). Located at Warri, on the western coast of the Niger delta, it will provide some products for export after the nation's domestic needs are met. The Warri refinery and a much similar one being built at Kaduna will give the nation an export capability of about 9 million mT/yr.

Demand for motor gasoline in the profiled African nations cannot be forecast from the data available at this time, since the effects of new affluence in the oil-producing countries have had

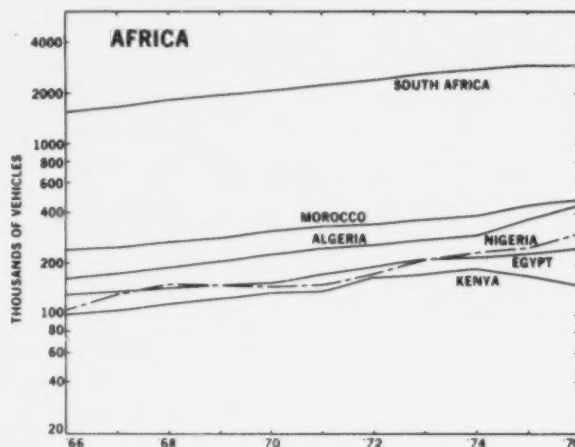


Figure AF-2. Rates of Growth in African Motor-Vehicle Population

too little time yet to smooth into trends. Figure AF-2 shows recent growth of motor-vehicle registrations in the nations surveyed.

Gasoline Quality

As can be seen from Table AF-2, gasoline antiknock quality varies widely among the African nations, but generally is low compared with U.S. and European standards. As in South America and other developing areas, imported motor vehicles have usually been equipped with low-compression "export" engines to permit use of the gasolines indigenously available. However, this practice tends to change as the nations' overall economy improves. This will be seen in the antiknock-quality and premium-grade sales figures of the Middle Eastern oil-producing nations.

Reference to Table AF-2 reveals that Algeria already has premium-grade gasoline of an anti-knock quality comparable to that anywhere in the world, and Morocco is not far behind. In Morocco, the somewhat lower-octane premium accounts for 60% of total gasoline sales. In Nigeria, where regular-grade rates only about 83 RON and premium only about 93 RON, the premium grade takes 80% of the total motor-gasoline market. And in South Africa, where regular rates about 87 RON and premium 93 RON, the premium grade accounts for 90% of motor-gasoline sales.

TABLE AF-2
Typical African Gasoline Quality, 1968-78, and Latest Sales
average of range for the countries

Nation	1968	1970	1972	1974	1976	1978	10 ³ Sales* mT/yr
Algeria							
Premium RON	97.5	98.8	98.5	97.0	97.5	98.0	681†
Premium MON	88.0	89.8	89.5	88.5	89.5	—	
Pb Content, g/l	0.43	0.53	0.46	0.58	0.66	0.55	
Regular RON	90.5	90.5	90.5	90.5	90.5	90.0	
Regular MON	84.5	85.5	85.5	84.0	85.5	—	
Pb Content, g/l	0.43	0.52	0.53	0.56	0.48	0.55	
Egypt							
Premium RON	85.5	85.5	87.0	82.0	85.0	85.0	504
Premium MON	82.5	82.5	—	—	—	—	
Pb Content, g/l	0.64	0.65	0.84	0.84	0.67	0.62	
Regular RON	73.0	78.0	70.0	70.0	73.0	—	335
Regular MON	70.0	75.0	—	—	70.0	70.0	
Pb Content, g/l	0.21	0.22	0.40	0.40	0.31	0.32	
Kenya							
Premium RON	94.5	95.0	95.0	94.0	95.0	95.0	139
Premium MON	86.5	88.0	88.0	88.0	—	—	
Pb Content, g/l	0.60	0.68	0.71	0.77	0.84 Max	0.80	
Regular RON	83.0	84.0	83.5	84.0	83.0	83.0	98
Regular MON	79.5	80.0	—	—	—	—	
Pb Content, g/l	0.38	0.42	0.42	0.54	0.63 Max	0.77	
Morocco							
Premium RON	96.0	96.0	96.0	95.5	95.5	96.0	250
Premium MON	85.5	85.5	88.0	88.0	—	—	
Pb Content, g/l	0.49	0.56	0.51	0.57	0.63 Max	0.54	
Regular RON	88.5	89.0	89.0	88.5	88.0	87.5	154
Regular MON	83.0	84.5	83.0	83.0	—	—	
Pb Content, g/l	0.36	0.40	0.31	0.37	0.63 Max	0.35	
Nigeria							
Premium RON	93.5	94.0	94.0	93.0	93.0	93.0	1,194
Premium MON	82.5	—	—	—	—	—	
Pb Content, g/l	0.58	0.60	0.57	0.64	0.66 Max	0.66 Max	

Table AF-2 (Continued)

	1968	1970	1972	1974	1976	1978	Sales* 10 ³ mT/yr
Nigeria (continued)							
Regular RON	83.5	85.0	84.0	83.5	83.0	83.0	264
Regular MON	78.5	—	—	—	—	—	
Pb Content, g/l	0.40	0.44	0.61	0.57	0.66 Max	0.66 Max	
South Africa							
Premium RON	93.5	93.5	95.5	93.0	93.0	93.0	—
Premium MON	88.0	88.0	85.0	83.0	86.0	84.0	
Pb Content, g/l	0.60	0.72	0.72	0.84	0.83 Max	0.44	
Regular RON	83.5	84.0	88.0	87.0	87.0	87.0	—
Regular MON	80.0	80.0	80.0	81.0	80.0	82.0	
Pb Content, g/l	0.40	0.55	0.55	0.33	0.83 Max	0.10	

*Latest year available

†Combined sales of premium and regular

MIDDLE EAST

Current Situation

Middle Eastern crude-distillation capacity (including the Arab states and Israel) totaled 152 million mT/yr at the end of 1977. Of that total, Israel, with 10.1 million mT/yr, accounts for only about 7%. As shown in Table ME-1, the three largest refining nations of the area – Iran, Kuwait, and Saudi Arabia – account for 30%, 23%, and 19%, respectively, for a total of 72%.

Bahrain accounts for about 8% of Middle East crude capacity, Iraq for 6%, and South Yemen for 5%. Together, the seven nations listed in Table ME-1 account for 98% of total Middle East crude-distillation capacity. They also account for 92% of the area's hydrogen-processing capacity,

97% of its catalytic-reforming capacity, and 88% of its catalytic-cracking capacity.

Bahrain and South Yemen export most of the refined products that they produce – Bahrain about 95% and South Yemen about 70%.

Even with production from wells in the occupied Sinai, Israel has been forced to import almost all the crude it refines. With the exception of Bahrain and South Yemen, the other Middle Eastern nations covered in this survey produce far more crude oil than they refine. Bahrain, so far, has been a refiner of Middle Eastern crude for export. It obtains the necessary crude about 25% indigenously and 75% from neighboring countries. South Yemen imports and refines Middle Eastern crude to meet its domestic needs.

TABLE ME-1
Middle East Refining Capacities

Million Metric Tons per Year as of Jan. 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
Iran	45.6	4.5	2.5	1.5	3.3
Kuwait	35.6	11.6	0.9	—	—
Saudi Arabia	29.3	2.1	1.9	0.4	1.4
Bahrain	12.5	4.2	0.6	1.5	12.0
Israel	10.1	3.8	1.1	0.4	4.0
Iraq	8.5	0.6	0.2	—	—
South Yemen	7.1	—	0.4	—	—

Outlook for the Future

As shown in Figure ME-1, demand for refined products began to grow rapidly in Iran and Saudi Arabia even before the tremendous post-1973 increases in their economies. Over the present survey period, product demand in both countries more than doubled. By contrast, demand has been quite flat in Kuwait, except for a brief spurt in the 1969-71 period. Since 1972, Iraq's demand has also been flat.

Israel's demand rose sharply in 1967 and more than doubled by 1973. But, in the face of quadrupled world crude prices, it declined slightly in 1974 and 1975. Since then, it has shown signs of resuming growth at the 8-9% annual rate it showed in the five-year period 1968-73. Its growth during the past two years averages out to an 8% annual increase.

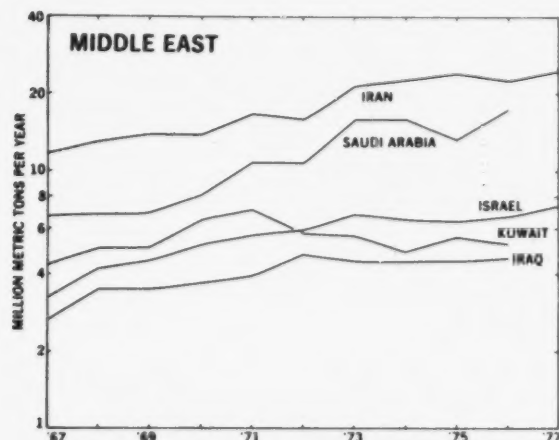


Figure ME-1. Trends in Total Domestic Demand in Middle Eastern Nations

Domestic demand for gasoline in the Middle East probably will accelerate in the now-affluent OPEC nations and decelerate in Israel, which has to import most of its oil. Figure ME-2 shows past rates of growth in Middle Eastern motor-vehicle registrations.

Gasoline Quality

As shown in Table ME-2, gasoline antiknock quality now is quite good in the Middle Eastern countries surveyed, except for Iraq and Israel. Iran had a 97-RON premium throughout the survey period, and Saudi Arabia had a premium rating 95 RON. Kuwait got a 98-RON premium in 1970. Prior to the 1970s, Middle Eastern anti-knock quality was quite low. However, all of them now have at least one grade rating as high as the regulars of the major car-producing nations. Since most of the world's passenger-car engines now have lower compression ratios than they did in 1970, gasoline antiknock quality is not likely to be increased much in the Middle East during the near future.

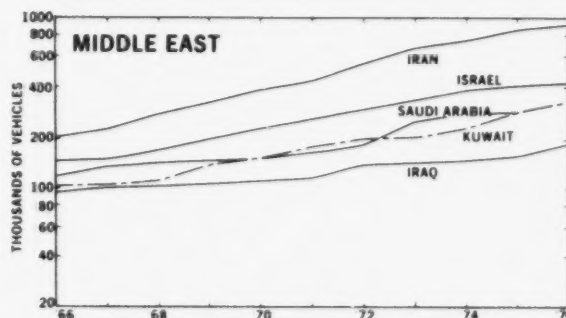


Figure ME-2. Rates of Growth in Middle Eastern Motor-Vehicle Population

TABLE ME-2
Typical Middle Eastern Gasoline Quality, 1968-78, and Latest Sales
average of range for the countries

Nation	1968	1970	1972	1974	1976	1978	Sales* 10 ³ mT/yr
Iran							
Premium RON	97.0	97.0	97.0	97.0	97.0	97.0	
Premium MON	87.0	87.0	87.0	87.0	—	—	
Pb Content, g/l	0.56	0.56	0.56	0.56	0.56**	0.56**	2,238†
Regular RON	90.0	90.0	87.5	90.0	90.0	90.0	
Regular MON	83.0	83.0	—	83.0	—	—	
Pb Content, g/l	0.56	0.28	0.45	0.56	0.56**	0.56**	
Iraq							
Premium RON					93.0	93.0	
Premium MON	No premium grade until 1975				86.0	86.0	
Pb Content, g/l					0.79**	0.79**	
Regular RON	88.0	88.0	88.0	88.0	88.0	88.0	471†
Regular MON	82.0	82.0	82.0	82.0	82.0	82.0	
Pb Content, g/l	0.42	0.42	0.42	0.42	0.79**	0.79**	
Israel							
Premium RON	91.0	91.0	94.0	96.0	94.0	94.0	
Premium MON	83.0	83.0	—	—	—	86.0	
Pb Content, g/l	0.42	0.42	0.59	0.59	0.59	0.42**	712†
Regular RON	83.0	83.0	83.0	83.0	83.0	83.0	
Regular MON	78.0	78.0	78.0	78.0	—	78.0	
Pb Content, g/l	0.42	0.42	0.42	0.42	0.59	0.42**	
Kuwait							
Premium RON	—	98.0	98.0	98.0	98.0	98.0	72
Premium MON	—	90.0	90.0	90.0	89.0	89.0	
Pb Content, g/l	—	0.66	0.57	0.61	0.61	0.54	
Regular RON	90.0	90.0	90.5	90.0	90.0	90.0	534
Regular MON	82.0	82.0	83.5	83.0	83.0	83.0	
Pb Content, g/l	0.53	0.45	0.37	Nil	0.11	0.51	
Saudi Arabia							
Premium RON	95.0	95.0	95.0	95.0	95.5	95.0	1,179
Premium MON	87.0	87.0	87.0	86.0	88.0	—	
Pb Content, g/l	0.84	0.84	0.84	0.84	0.84**	0.84**	
Regular RON	83.0	83.0	83.0	83.0	83.5	83.0	222
Regular MON	79.0	80.0	80.0	80.0	—	—	
Pb Content, g/l	0.84	0.84	0.84	0.84	0.84**	0.84**	

*Latest year available

†Combined sales of premium and regular

**Maximum

FAR EAST

Current Situation

As can be seen from Table FE-1, Australia's 35-36 million mT/yr of crude-distillation capacity makes it the largest refining nation, other than Japan, in the Far Eastern area. (Singapore, which has about 46 million mT/yr of crude capacity, is not included here since its refineries are operated primarily for exporting purposes.)

During the three years since our 1975 survey, Indonesia's crude capacity was expanded by 23%, South Korea's by 12%, and Taiwan's by 75%. That of the Philippines declined 4%, however, presumably from retirement of older facilities.

Outlook for the Future

Only one of the five Far Eastern nations surveyed here produces enough crude oil to meet domestic demand. That nation, Indonesia, produces six or seven times as much oil as it refines. Thus, future expansion of its refining industry is not subject to the supply and price uncertainties faced by the other four nations. As yet, Indonesia is not an appreciable net exporter of petroleum products. However, like other nations amply endowed with crude, it may decide to build one or more export refineries as a means of increasing income from the oil that it produces beyond its own needs.

South Korea and the Philippines have no appreciable indigenous crude production. And

Taiwan produced only about 2% of the crude it refined in 1976.

Australia has, for some years now, produced more than half of the crude oil it refines – 68% in 1974 and 71% in 1976.

Australia's domestic demand about doubled in the nine-year period 1964-73, then showed the typical importer-nation reaction to quadrupled prices for crude oil. As can be seen from Figure FE-1, the 1973-74 oil shock slowed, but far from stopped, growth of domestic demand in all of the surveyed Far Eastern nations.

To help keep pace with South Korea's soaring domestic demand, its Ulsan and Yosu refineries are each scheduled for 7.5 million-mT/yr (150,000-b/d) expansions, and the Incheon refinery for a 2 million-mT/yr (40,000-b/d) expansion – all to be completed by 1981. Plans for the nation's fourth and fifth refineries reportedly are underway. One of them would be a 12.5 million-mT/yr (250,000-b/d) plant, owned 50% by South Korean interests and 25% each by Kuwait and Saudi Arabia.

In Australia, Ampol Refineries Ltd. reportedly will more than double the capacity of its Brisbane refinery – from 54,000 b/d to 112,000 b/d (or from about 2.7 to 5.6 million mT/yr) – to help meet Queensland demand for the next ten years.

TABLE FE-1
Far East Refining Capacities

Million Metric Tons per Year as of January 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
Australia	35.5	11.4	6.9	6.4	18.0
Indonesia	26.4	0.9	1.5	1.0	3.8
S. Korea	23.8	2.0	1.0	—	—
Taiwan	21.3	5.7	2.0	0.4	0.2
Philippines	12.7	5.3	1.7	1.2	0.9

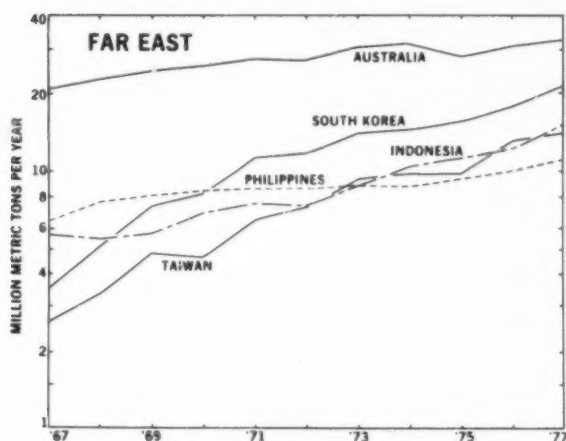


Figure FE-1. Trends in Total Domestic Demand in Far Eastern Nations

And Amoco Australia Pty., Ltd., is increasing the capacity of its Bulwer Island refinery from 30,500 b/d to 45,000 b/d (from 1.5 to 2.25 million mT/yr).

Indonesia's planned Batam Island refinery now is scheduled for completion early in 1983. It reportedly will be designed for a capacity of 200,000 b/d, or about 10 million mT/yr. Plans to add an \$800-million hydrocracker at the Dumai refinery in Sumatra are still very active, according to the U.S. Export-Import Bank. Hydrocracking reportedly is needed to break down the waxy low-sulfur residue from refining of Indonesia's Minas crude.

Announced expansion of Taiwan's Kaohsiung refinery reportedly will increase crude capacity by 100,000 b/d (5 million mT/yr) and add a 25,000-b/d (1.25 million-mT/yr) fluid catalytic cracker.

The Philippines' Bataan refinery is said to be at the engineering-study stage in a contemplated 25,000-b/d (1.25 million-mT/yr) expansion of crude-distillation capacity.

As shown in Figure FE-2, Australia's motor-vehicle population grew at an almost constant rate of 5% per year during the survey period. Although not as smooth from year-to-year, the nation's domestic demand for gasoline increased at the same 5% average annual rate.

In Taiwan, motor-vehicle population grew an average 21% per year and gasoline demand an average 20%. South Korea's average rates of

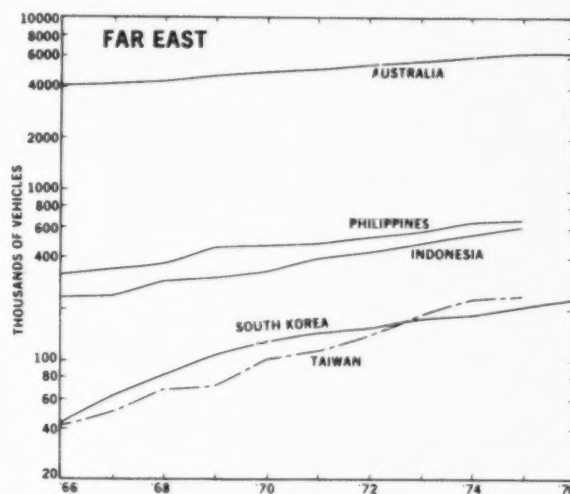


Figure FE-2. Rates of Growth in Far Eastern Motor-Vehicle Population

growth were 18% for vehicles and 18% for gasoline. Indonesia's average annual rates were: vehicles, 11%; gasoline, 9%. And the Philippines showed average growth rates of 9% for vehicles and 5% for gasoline.

That such high rates of growth in vehicle population and gasoline demand will prevail during the next ten years would seem unlikely, particularly in the nations that must import all or almost all of their crude oil. However, these are developing countries with a large unfilled first-time demand for personal cars.

Gasoline Quality

As shown in Table FE-2, Australia's 97 to 98 RON premium-grade gasolines account for about 88% of the motor gasoline sold in the country. In Indonesia prior to 1973, even the premium-grade gasolines were below 90 RON, but the nation now has 98-RON premiums. South Korean premiums, which rate about 95 RON, account for around 20% of the nation's total motor-gasoline sales. In the Philippines, premium-grade gasoline apparently is tailored to satisfy the majority of cars made today, but not higher-compression cars built eight to ten years ago. As can be seen from the table, Philippine premiums average about 94 RON and account for around 80% of the total motor-gasoline market. Taiwan has relatively high-octane premiums (96-97 RON), but quite low-octane regulars (83-84 RON).

TABLE FE-2
Typical Far Eastern Gasoline Quality, 1968-78, and Latest Sales
average of range for the countries

Nation	1968	1970	1972	1974	1976	1976	Sales * 10 ³ mT/yr
Australia							
Premium RON	97.2	98.1	98.5	97.5	97.5	97.5	8,702
Premium MON	87.5	89.4	90.0	89.5	89.5	88.5	
Pb Content, g/l	0.50	0.53	0.52	0.58	0.58	0.67	
Regular RON	87.5	89.0	89.5	89.5	89.5	88.0	1,135
Regular MON	82.0	82.5	80.0	82.5	83.5	82.5	
Pb Content, g/l	0.38	0.44	0.44	0.21	0.21	0.60	
Indonesia							
Premium RON	87.0	86.0	86.5	98.0	98.0	98.0	110
Premium MON	84.0	84.0	84.0	84.0	—	—	
Pb Content, g/l	0.28	0.28	0.42	0.42	0.84 Max	0.79 Max	
Regular RON	78.0	77.5	78.0	87.0	87.0	87.0	2,109
Regular MON	75.5	75.5	75.5	80.0	—	—	
Pb Content, g/l	0.23	0.51	0.49	0.46	0.84 Max	0.66 Max	
South Korea							
Premium RON	One Grade	95.0	95.0	95.0	96.0	95.0	96
Premium MON		86.0	89.0	87.0	—	—	
Pb Content, g/l		0.60	0.53	0.55	0.63 Max	0.63 Max	
Regular RON	88.0	87.0	87.0	86.0	86.0	85.0	397
Regular MON	83.0	82.0	82.0	81.0	—	—	
Pb Content, g/l	0.45	0.49	0.49	0.52	0.63 Max	0.63 Max	
Philippines							
Premium RON	96.0	95.5	95.5	94.0	93.0	94.0	4,169
Premium MON	86.5	85.0	85.0	84.0	—	85.0	
Pb Content, g/l	0.49	0.39	0.41	0.28	0.33	0.58	
Regular RON	84.0	83.5	83.5	82.0	81.0	82.0	1,073
Regular MON	78.0	77.5	78.5	78.5	—	80.0	
Pb Content, g/l	0.45	0.17	0.20	0.20	0.18	0.22	
Taiwan							
Premium RON	95.5	95.5	96.0	96.0	95.5	96.5	984†
Premium MON	86.5	86.5	87.0	87.0	87.0	—	
Pb Content, g/l	0.68	0.76	0.77	0.65	0.66 Max	0.41 Max	
Regular RON	79.5	79.5	79.5	83.0	82.5	83.5	
Regular MON	75.5	76.5	76.5	79.0	79.0	—	
Pb Content, g/l	0.68	0.63	0.42	0.66	0.63 Max	0.32 Max	

*Latest year available.

†Combined sales of premium and regular

SOUTH AMERICA

Current Situation

Our 1967 survey pointed out that the overall economies of most of the South American refining nations were expanding 5% or more annually. We then expressed belief that "any or all of the nations surveyed here have the potential for considerably more rapid economic growth than they have shown to date." At that time, Venezuela's annual growth of gross national product (GNP) was averaging about 7% per year, and that of Brazil about 6%. Argentina was showing a 2% average gain in GNP, Chile 3.5%, Colombia 4.6%, and Peru 6%.

During the present 1967-77 survey period, Brazil's domestic demand for petroleum products grew rather sporadically at an average annual rate of 10%, increasing 2.7-fold (see Figure SA-1). That of Argentina, however, grew at annual rates of only 3-4% from 1967 through 1972, took a 9% spurt in 1973, then declined as a result of the sharply increased post-1973 prices for imported crude oil. Argentinian demand showed signs of a recovery in 1977, but still finished the survey period 4% lower than its 1973 level.

Venezuela's domestic demand increased 53% over the ten-year survey period. During the years 1969-73, it rose at an average annual rate of 7%. But, rather unaccountably for an oil-rich nation, it flattened in the 1973-76 period. In 1977, however, it rose about 12%.

Domestic demand in Colombia, Peru, and Chile was at about the 4 million-mT/yr level in 1967. As shown in the intertwined curves of Figure SA-1, it rose over the survey period about 85% in Colombia and 36% in Peru. Chile's erratic 1967-76 demand pattern ended only about 5% higher than it began.

Ecuador's demand tripled over the survey period. From 1969 to 1972, it rose at an average rate of 15% per year. Following a much slower period of growth in 1973 through 1975, it again took off at an average annual rate of 20% in 1976 and 1977.

As shown in Table SA-1, the two largest consumers, Brazil and Argentina, have cor-

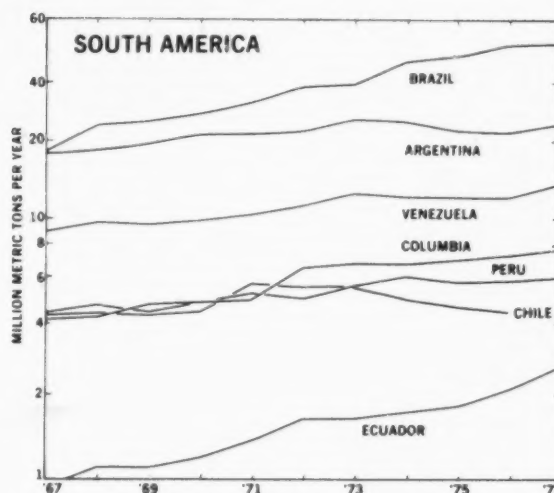


Figure SA-1. Trends in Total Domestic Demand in South American Nations

respondingly large crude-distillation and downstream-processing facilities. But the No. 3 consumer, Venezuela, has by far the greatest crude-distillation capacity because of its role as a major exporter of petroleum products. Since its primary export product is residual fuel oil, it has a relatively low ratio of catalytic-cracking to crude-distillation capacity. Chile, Colombia, Ecuador, and Peru all have refining capacities that would be expected from their domestic demand.

Outlook for the Future

South America's only major exporter of petroleum products, Venezuela, has launched a refinery-modernization program aimed at providing flexibility to cope with fluctuations in its traditional residual-fuels market — and to increase gasoline production. State-owned Petroleos de Venezuela has announced that it will spend about \$600 million at the Lagoven Amuay refinery for a 2.6 million-mT/yr (52,000-b/d) Exxon R&E Flexicoker, a 3.7 million-mT/yr (74,000-b/d) Flexicracker, a 600,000-mT/yr (14,200-b/d) alkylation unit, and a 320,000-mT/yr (7,500-b/d) isomerizer. It earlier announced a somewhat similar project for Llanoven's El Palito refinery.

TABLE SA-1
South American Refining Capacities
 Million Metric Tons per Year as of Jan. 1, 1978

Nation	Crude Distillation	Hydrogen Processing	Catalytic Reforming	Catalytic Cracking	Cat. Cracking as % Distillation
Venezuela	72.3	16.0	0.9	2.3	3.2
Brazil	58.1	0.6	0.9	9.3	16.0
Argentina	32.8	3.0	1.6	4.1	12.5
Peru	8.6	0.1	—	1.0	11.6
Colombia	8.3	0.3	0.3	2.1	25.3
Chile	6.5	—	0.4	1.4	21.5
Ecuador	4.8	—	—	—	—

The "horizontal expansion" of Venezuela's Amuay refinery will not increase its 32.5 million-mT/yr (630,000-b/d) crude capacity. Instead, it will greatly broaden the plant's refining pattern. Production of high-sulfur fuel oils will drop from 9.8 million to 5.4 million mT/yr (from 200,000 to 111,000 b/d). Output of low-sulfur fuel oils will increase from 6.6 million to 7.9 million mT/yr (from 135,000 to 162,000 b/d). Components for the gasoline pool will rise from 2.1 million to 4.5 million mT/yr (from 49,000 to 106,000 b/d). Yield of residual fuel will decrease from 9.9 million to 6.3 million mT (from 182,000 to 116,000 b/d).

Brazil has just completed a \$2-billion petrochemical complex at Camacari, Bahia. Based on a 380,000-mT/yr (840 million-lb/yr) ethylene plant, it has the capacity to process more than 1.6 million mT/yr (about 25,000 b/d) of naphtha and gas oil, plus 500,000 mT/yr (70 million cubic feet per day) of natural gas. Its refinery-type facilities include a Platformer and units for recovery of benzene, toluene, and xylenes, plus a toluene disproportionator. Units to be added soon will include facilities to produce detergent precursors. One unit will produce normal olefins by catalytic dehydrogenation of normal paraffins. The olefins will feed another unit producing linear alkyl-benzenes for use in making biodegradable

detergents. Thus, Brazil is well on its way to converting crude into high-value products.

Expansion of Ecuador's new 2.8 million-mT/yr (55,000-b/d) Esmeraldas refinery already is planned. The government has asked a U.S. engineering company to study ways capacity can be raised 25-30% to help keep pace with rapidly rising domestic consumption.

Peru, with a 1977 domestic demand of 6 million mT (120,000 b/d), by early 1978 was indigenously producing crude oil at a rate of almost 7 million mT/yr (about 140,000 b/d). So near-future growth of Peru's domestic demand is not likely to be held down by world oil prices.

Some idea of how gasoline demand may grow in South America can be obtained from Figure SA-2, which shows growth of motor-vehicle registrations in the surveyed nations. As can be seen, Brazil's motor-vehicle population rose at a remarkably consistent rate of 12% a year, more than tripling over the ten-year survey period. Argentina's rate of vehicle increase also was remarkably consistent, averaging 9% annually. Over the survey period, it more than doubled. While not so consistent in year-to-year percentage increases, motor-vehicle population in the other surveyed nations rose over the years as follows: 2.4-fold in Venezuela, 2-fold in Colombia, 1.8-fold in Peru, and 2.1-fold in Chile.

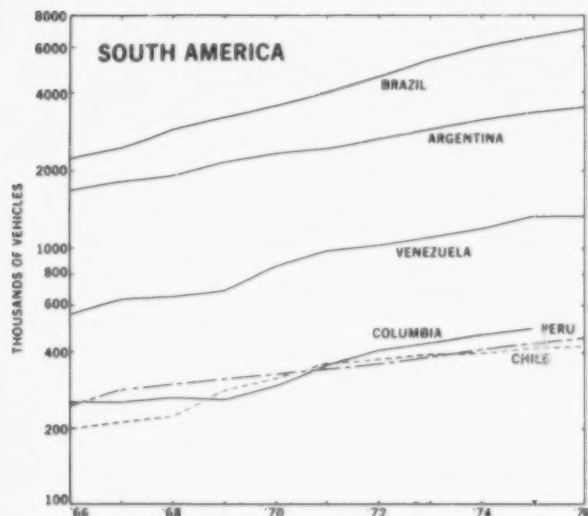


Figure SA-2. Rates of Growth in South American Motor-Vehicle Population

Gasoline Quality

As shown in Table SA-2, premium-grade gasolines in South America have about the octane quality expected in U.S., West European, and Japanese regulars. Since most U.S., European, and Japanese cars are now built to operate on the regulars available in their countries of origin, all of the surveyed countries except Brazil and Ecuador now have a premium grade that will meet the octane requirements of regular-production foreign cars. For many years, however, low-octane gasolines dominated the scene in South America, and foreign-made cars imported by South Americans had to come equipped with special low-compression "export" engines. While premiums still account for only a small proportion of total gasoline sales in the other surveyed countries, they now outsell regulars in Argentina.

TABLE SA-2

Typical South American Gasoline Quality, 1968-78, and Latest Sales
average of range for the countries

Nation	1968	1970	1972	1974	1976	1978	Sales,* 10 ³ mT/yr
Argentina							
Premium RON	90.5	93.0	95.0	95.0	94.0	94.5	2,477
Premium MON	83.0	84.5	84.5	84.5	—	83.0 Min	
Pb Content, g/l	0.51	0.67	0.60	0.58	0.50	0.53	
Regular RON	78.0	83.3	84.0	84.0	84.0	84.5	2,100
Regular MON	75.5	78.0	77.5	77.5	—	—	
Pb Content, g/l	0.54	0.57	0.56	0.56	0.30	0.27	
Brazil							
Premium RON	87.0	87.0	90.2	89.5	90.0	90.0	129
Premium MON	83.0	83.0	81.9	82.5	—	82.0 Min	
Pb Content, g/l	0.58	0.57	0.59	0.57	0.84 Max	0.84 Max	
Regular RON	79.0	79.0	79.3	81.5	80.0	80.0	10,664
Regular MON	74.0	74.0	74.6	73.0	—	73.0 Min	
Pb Content, g/l	0.42	0.52	0.41	0.52	0.84 Max	0.84 Max	

Continued on next page

TABLE SA-2 (Continued)

Nation	1968	1970	1972	1974	1976	1978	Sales* 10 ³ mT/yr
Chile							
Premium RON	93.5	94.0	94.0	94.0	93.0	93.0	182
Premium MON	82.5	82.0	82.0	82.0	82.0	82.0	
Pb Content, g/l	0.18	0.40	0.49	0.49	0.84 Max	0.84 Max	
Regular RON	82.0	81.5	82.0	82.0	81.0	81.0	724
Regular MON	74.5	75.5	75.5	75.5	—	—	
Pb Content, g/l	0.21	0.49	0.56	0.49	0.40 Max	0.40 Max	
Colombia							
Premium RON	95.0	95.0	95.0	95.0	93.5	93.0	135
Premium MON	84.5	84.5	85.0	—	—	—	
Pb Content, g/l	0.43	0.44	0.46	0.84	0.84 Max	0.84 Max	
Regular RON	82.5	82.5	82.5	83.5	82.5	83.0	2,320
Regular MON	75.0	74.5	75.0	—	—	—	
Pb Content, g/l	0.36	0.36	0.36	0.26	0.40 Max	0.40 Max	
Peru							
Premium RON	96.0	96.5	95.5	95.0	95.0	95.0	46
Premium MON	85.0	84.0	84.0	—	—	—	
Pb Content, g/l	0.82	0.52	0.21	0.21	0.84 Max	0.84 Max	
Regular RON	85.0	86.8	89.0	85.0	84.0	84.0	1,292
Regular MON	82.0	81.0	82.0	—	—	—	
Pb Content, g/l	0.56	0.32	Nil	Nil	0.84 Max	0.84 Max	
Venezuela							
Premium RON	96.0	95.5	95.0	95.0	95.0	95.0	914
Premium MON	88.5	88.5	88.5	89.0	—	—	
Pb Content, g/l	0.71	0.66	0.75	0.84	0.84 Max	0.84 Max	
Intermediate RON	85.0	85.5	84.0	84.0	84.0	84.0	
Intermediate MON	82.0	80.5	78.0	81.0	—	—	
Pb Content, g/l	0.49	0.52	0.52	0.63	0.84 Max	0.84 Max	3,718†
Regular RON	75.5	75.5	75.5	74.0	74.0	74.0	
Regular MON	72.5	72.5	73.0	—	—	—	
Pb Content, g/l	0.14	0.42	0.42	0.05	0.84 Max	0.84 Max	
Ecuador							
Premium RON	81.0	81.0	82.0	81.0	—	80.0	
Premium MON	—	—	—	—	80.0	—	
Pb Content, g/l	0.84	0.84	0.84	0.84	0.84 Max	0.84 Max	
Regular RON	61.5	61.5	63.0	63.0	—	63.0	
Regular MON	—	—	—	—	70.0	—	
Pb Content, g/l	Nil	Nil	Nil	Nil	Nil	Nil	

*Last year available

†Combined sales of intermediate and regular

MEETING FUTURE REQUIREMENTS

A pattern of growth in future world demand for petroleum has been forecast by Dr. Arnold E. Safer, chief energy economist for Irving Trust Co. (New York), on the assumption that it will follow growth in GNP (gross national product) "despite government rhetoric and despite attempts to substitute alternative energy sources." When he first announced his forecasts, late in 1976, he pointed out that world demand in 1974 was down 3.9% from that in 1973 and that the 1975 demand had declined an additional 2.9%. He estimated a 5.5% recovery-type increase in 1976, followed by growth rates of 1.5% in 1977 and 3.2% annually thereafter through 1980.

Although the domestic-demand curves for the countries surveyed here differ in percentage changes, it is interesting to note that most of them show the pattern cited by Dr. Safer.

Reviewing his forecasts early in 1978, Dr. Safer predicted world oil consumption in the non-Communist world at 51 million b/d (2.55 billion mT/yr) in 1978, 53 million b/d (2.65 billion mT/yr) in 1979, and 54.5 million b/d (2.73 billion mT/yr) in 1980, compared with 49.5 million b/d (2.48 billion mT/yr) in 1977. For each year, the predicted annual growth is 3.2%.

Dr. Safer bases his forecasts on projected GNP growth rates of 4% in the United States, 2.5% in Western Europe, and 5% in Japan. He foresees an economic downturn at the end of 1980 or early in 1981 – not as severe as the one in 1974-75, but having a noticeable effect on oil consumption. However, he believes the recovery from that downturn will be strong. Thus, he expects the non-Communist world's oil demand to decline to 52.7 million b/d (2.64 billion mT/yr) in 1981, recover to 55 million b/d (2.75 billion mT/yr) in 1982, and rise to about 60.5 million b/d (3.03 billion mT/yr) by 1985.

"The importance of the projected recession and recovery lies in their relation to the non-cyclical growth of supply," according to Dr. Safer. "That is, large excess supplies in the oil market can be expected by late 1980 or early 1981, representing a combination of declining demand and increasing supply – a situation likely

to persist for some time and one that represents a significantly different perception of the world oil market than is prevalent today."

Additional optimism regarding long-term oil supply can be derived from the Petroleum Engineer's observation (Oct. 78, p. EM2) that "Every time energy prices rise, a new deposit of oil/natural gas becomes economic for the first time. Members of the Organization of Petroleum Exporting Countries, every time they increase prices, provide more of their own competition in non-member countries. The largest new areas to offer potential profit from higher prices are offshore operations. They are costly, but some pay out at current market prices for oil and natural gas, and prospects are for higher prices in 1979."

Speaking before the Oxford Energy Policy Club, the president of Institut Francais du Petrole, M. Pierre Desprairies, recently pointed out that the Western world will, in the next decade, have to make the transition from an economic system in which almost all oil was produced at a cost (not price) of 30 cents to \$4 per barrel to one in which energy supplies will come increasingly from offshore oil costing \$7-8 to produce. The costs of competitive fuels, in terms of oil equivalent, will be about \$5-6 for liquefied gas, \$5-10 for coal, \$7-9 for nuclear energy, and \$8-15 for unconventional oil (from shale, tar sands, etc.). All conventional oil, including that obtained deep offshore and through secondary recovery, presumably will be used before consumers have to resort to shale oil at, say, \$20 a barrel (\$145 per mT).

Despite Dr. Safer's doubts regarding the efficacy of "government rhetoric," increased efficiency in the energy consumption of various surveyed nations shows up clearly in statistics recently released by the International Energy Agency (IEA). Reported in terms of extra metric tons of oil equivalent (mToe) required to raise gross domestic product (GDP) by \$1,000 in constant 1970 U.S. dollars, the figures show that, on average, less than half as much new energy is required now as was required before the 1973 oil

TABLE W-1
Energy Conservation in IEA Nations

Based on Metric Tons of Oil Equivalent (mToe)

Nations	Use, 10 ⁶ mToe		Growth %/yr	Extra mToe for \$1000 GDP	
	1972	1977		1960-72	1972-77
France	164	178	1.70	0.86	0.54
W. Germany	250	258	0.62	0.99	0.30
Italy	125	131	0.91	1.59	0.31
Japan	312	360	2.94	1.02	0.67
Netherlands	59	63	1.36	1.65	0.43
Spain	51	68	6.09	1.10	1.63
Sweden	45	48	1.17	1.08	0.81
Switzerland	21	23	1.56	n.a.	n.a.
United Kingdom	215	212	-0.27	0.73	*
United States	1,691	1,767	0.88	1.11	0.34
IEA as a whole	3,108	3,309	1.26	1.06	0.48

*The U.K. increased GDP while decreasing total energy use.

embargo. Table W-1 shows such data for individual IEA nations and compares total national energy consumptions in 1972 with those in 1977.

Any and all plans for energy conservation – whether national, regional, or worldwide – must take into account increasing demand for light petroleum fractions. As private passenger-car ownership grows, so does domestic demand for gasoline – in almost direct proportion. And as national economies grow, so does demand for multitudinous consumer products made from petrochemical feedstocks. In much, if not most, of the world, the main petrochemical feedstock is naphtha. Thus, competition between gasoline and petrochemicals for the naphtha fractions available can be expected to increase worldwide.

As shown in Table W-2, naphtha is the almost exclusive source of the world's olefin-based and aromatics-based chemicals, plastics, textiles, etc. An idea of the competition for the toluene and xylenes produced worldwide in catalytic reformers, catalytic crackers, and steam crackers is given by Table W-3. As can be seen, only small percentages of total toluene and xylene production were separated from the gasoline pool and

used in other ways. According to the Hyplan study from which the table comes, on a worldwide basis, 44% of the extracted toluene was dealkylated to benzene, 2.5% was disproportionated to benzene and xylenes, 20% was put to solvent uses, 14.5% was used to synthesize chemicals, and 19% found its way back into gasoline. Of the xylenes extracted, 67% was separated into the three isomers for petrochemical uses, 17% was used for solvent purposes, and 16% was blended into gasoline.

The European Economic Community's chemical industry currently consumes 12% of the EEC's total energy requirement – 5% as feedstock and 7% as process energy. Bayer AG's chairman, Dr. Herbert Grunewald, said at CHEMRAWN I, the first of a series of international conferences on Chemical Research Applied to World Needs, held July 10-13, 1978, in Toronto, Canada. Pointing out that European refineries convert only 23% of their crude runs into naphtha, for which chemical and gasoline producers must compete, he called for the European chemical industry to make optimum use of the crude oil available to it.

TABLE W-2
Demand for Chemical Feedstocks

Million Metric Tons per Year

Area	Ethylene			Benzene*		
	1976	1980	1985	1976	1980	1985
United States						
Condensates	15.0	15.7	16.6			
Naphtha	8.4	16.7	26.0	9.5	13.5	17.0
Gas Oil	—	3.3	7.5			
Canada						
Condensates	0.3	0.6	0.8			
Naphtha	1.0	1.1	1.1	0.5	0.6	0.8
Gas Oil	—	—	—			
W. Europe						
Condensates	0.13	0.9	1.7			
Naphtha	36.1	35.6	43.0	8.3	10.0	12.5
Gas Oil	2.6	8.3	10.0			
Japan						
Condensates	—	—	—			
Naphtha	15.2	19.5	24.0	3.1	5.0	6.0
Gas Oil	—	—	2.0			

*Consumption of high-aromatic naphtha.

Source: Organization for Economic Cooperation and Development

Reserving oil and gas reserves for use as chemical feedstocks is "powerfully supported by recent findings of the Secretariat of the United Nations Economic Commission for Europe," the Petroleum Economist reported in its June 1978 issue. The Secretariat, it said, predicts that use of fossil fuels as chemical raw materials "will grow dramatically from about 490 million metric tons of coal equivalent (about 325 million mT/yr of oil equivalent) in 1974 to 1700-2000 million mTce (1125-1325 million mToe) in 1990." At that time, chemical uses are expected to account for 8-9% of total energy consumption – and their share is expected to increase to 11-14% by the turn of the century.

"Still more strikingly," the Petroleum Economist observes, "consumption of fuels as a

raw material may well be of the same order of magnitude in many parts of Europe and North America, within 30 or 40 years, as is the present total consumption of oil and natural gas for all purposes."

Such current informed opinions suggest that refineries of the future will have to be designed to get much greater naphtha-and-lighter yields than most of them (except in the U.S. and Canada) do at present. The concept of a "slaughterhouse" refinery that would convert practically all of the crude charged into petrochemical feedstocks, "utilizing everything but the squeal," has been advocated by Davy Powergas Inc.

To convert gas-oil fractions to methane, ethane, ethylene, aromatics, and synthesis gas,

Davy Powergas would use the Gas Recycle Hydrogenator (GRH) developed in the early 1970s by the British Gas Council for enriching town gas. To convert heavier feeds, the company would team the GRH with a Texaco partial-oxidation unit.

Such extreme processing as that advocated by Davy Powergas goes considerably beyond the new downstream-processing norm that may be expected to develop between now and the turn of the century. But some new norm clearly must be developed – one that converts crude into optimum yields of needed products that only oil can provide.

While this new international petroleum-refining industry is being evolved, the best possible use will have to be made of the naphtha supplies existing facilities can produce. This means, among other things, avoiding their waste by super-severe reforming to produce high gasoline octane numbers without lead antiknock compounds.

The effects of European restrictions on lead use in gasolines were recently assessed by CONCAWE, the international organization concerned with automotive emissions control in Europe. It concluded that the best policy would be to control lead use so that current consumption of lead antiknocks would remain constant over the next ten years. That could be done rather easily and inexpensively, but cutting back further would substantially increase refinery investment, operating costs, and consumption of crude oil.

Australia's National Energy Advisory Committee has gone a step farther, calling for higher national average octane quality and increased allowable lead content. It specifically recommended that:

1. The Research octane number of regular-grade gasoline be increased from 89 to 92.
2. The allowable lead content be increased to 0.65 g/litre (2.5 g/U.S. gallon) in those states where restrictions currently apply.
3. Lead filters (particulate traps) be fitted to new gasoline vehicles, beginning in 1980-82.

Speaking in favor of the recommendations, Member of Parliament Kevin Newman pointed out that the Commonwealth, its states, and industry, faced with dwindling supplies of indige-

nous crude oil, need to reach decisions that are in the best interests of energy resources as well as health and environment.

With a similar energy-conservation incentive, Italy's FEEMAS inter-industry group, which includes Fiat, ENI (the state-owned oil company), Esso, Mobil, and Alfa Romeo, has been studying the advantages of continued use of lead antiknocks combined with installation of lead traps in the exhaust systems of new vehicles. The summary of its Phase I report makes the following points.

1. Supposing that the results obtained in the various tests can be extended to the overall Italian car population, adoption of traps would reduce lead emissions from vehicles by about 40%.
2. In town, total lead emissions (airborne lead plus that which quickly settles to the ground) would be reduced by 55-65%. Airborne lead would be decreased by 35-40%.
3. Engine performance, power, and fuel economy would not deteriorate appreciably from the use of trap systems.
4. Use of the trap system in place of the standard exhaust system is equivalent to reducing the lead content in gasolines by one half.
5. Adopting the trap system concurrent with reduction of gasoline lead content from 0.6 to 0.4 gram per litre (2.3 to 1.5 g/gal) would reduce urban lead emission the same order of magnitude as was done in West Germany when lead concentration in gasoline was reduced to 0.15 gram per litre (0.57 g/gal).
6. "From an economic point of view, in terms of crude oil imports and refinery investments required to produce gasoline at 0.15 g Pb/litre of similar characteristics to the present one, the use of lead traps deserves careful consideration."

Gasoline-Quality Requirements

As shown in Table W-4, premium-grade gasolines of 97 to 100 RON are marketed throughout Western Europe and in Japan, as well as in the

TABLE W-3
Production and Use of Petroleum-Derived Toluene and Xylenes in 1977

Million Metric Tons

	United States	Western Europe	Japan	Other	World Total
Toluene Produced	24.40	12.70	3.1	n.a.	n.a.
Left in Gasoline	20.20	10.65	2.05	n.a.	n.a.
Dealkylated	1.85	1.30	0.25	1.00	4.40
Used Other Ways	2.35	0.75			
Xylenes Produced	24.80	11.80	2.90	n.a.	n.a.
Left in Gasoline	20.50	9.50	1.60	n.a.	n.a.
Used Other Ways	4.30	2.30	1.30	1.60	9.50

Source: Hydrocarbon Planning and Consulting Services (Hyplan).
 Oil and Gas Journal, 19 Dec 78, p. 36.

United States and Canada. In most of Western Europe, these high-octane gasolines now account for more than half of all motor gasoline sold. As the "Premium" column of the table shows, premium-grade gasolines substantially increased their share of the total gasoline market in most areas of the world during the present survey period. Notable exceptions are the United States and Canada, where introduction of exhaust-gas converters employing lead-sensitive catalysts has resulted in downgrading of engine compression ratios and ignition spark advance to permit operation on 91-RON unleaded gasoline.

As octane-number requirements rise, meeting them solely by catalytic reforming of virgin naphtha becomes uneconomic, if not impossible. Therefore, we may expect to see continued use of lead alkyl antiknock compounds. The most economical balance between processing and additive routes will be increasingly determined by linear programming on digital computers, as has become standard practice in the United States.

Where better front-end antiknock performance is needed, the lighter lead alkyls offer an immediate solution. By more evenly distributing antiknock quality to the cylinders, they can prevent the low-speed knock common with straight-run reformat gasolines, even those of premium grade.

Other Gasoline Additives

Introduction of devices to control automotive crankcase and exhaust emissions has increased the need for gasoline additives of the detergent-dispersant type. Such additives increase the performance life of positive-crankcase-ventilation (PCV) valves by as much as 75%. With exhaust-control systems in which air-fuel ratio is set to narrow limits, they also prevent malfunctions from accumulation of dirt in the carburetor.

Although the straight-run-reformat gasolines that predominate in the nations surveyed are relatively free of unstable components of the type that cause excessive gum formation in thermally cracked gasolines, most of them probably will continue to need small amounts of some antioxidant. With such effective synergistic combinations as an ortho-alkylated phenol and phenylene diamine, the average required dosage for such gasolines should be considerably less than the 9 grams or so per metric ton (2-3 pounds per 1000 barrels) used in the United States. Other additives for which need has long been recognized, such as anti-icing agents, metal deactivators, antirust agents, etc., will continue to be required, of course. However, growing use of multipurpose additives that perform several required functions simultaneously will reduce the number of additives handled in blending operations.

TABLE W-4

Gasoline Quality in 1978 and Premium Sales Ratio in Various Nations

Nation	Premiums		Regulars		% Premium
	RON	MON	RON	MON	
Europe					
Austria	98	88	88	84	71
Belgium	99	90	92	85	92
Denmark	100	91	94	88	61
Finland	98	87	93	85	58
France	98	89	90	84	81
Germany, W.	99	89	92	85	60
Greece	97	—	90	—	51
Italy	98	90	86	83	93
Netherlands	99	91	94	86	86
Norway	99	92	94	88	81
Portugal	98	89	86	82	72
Spain	98	89	90	84	80
Sweden	99	91	94	88	68
Switzerland	98	91	91	86	82
United Kingdom	98	90	91	85	74
Yugoslavia	98	91	86	82	45
Africa					
Algeria	98	—	90	—	—
Egypt	85	—	—	70	60
Kenya	95	—	83	—	59
Morocco	96	—	88	—	62
Nigeria	93	—	83	—	82
South Africa	93	84	87	82	—
Middle East					
Iran	97	—	90	—	—
Iraq	93	86	88	82	—
Israel	94	86	83	78	—
Kuwait	98	89	90	83	13
Saudi Arabia	95	—	83	—	84
Far East					
Australia	98	89	88	83	88
Indonesia	98	—	87	—	5
Japan	98	89	91	82	11
Korea, S.	95	—	85	—	19
Philippines	94	85	82	80	80
Taiwan	96	—	83	—	—
South America					
Argentina	94	—	84	—	54
Brazil	90	—	80	—	1
Chile	93	82	81	—	20
Colombia	93	—	83	—	5
Peru	95	—	84	—	3
Venezuela	95	—	84	—	20

CONCLUSION

A peaceful revolution appears to be going on in the world. During the 1967-77 survey period, world passenger-car registrations grew 6% a year — almost twice the rate in the United States. Of the 125 million private cars added to the world's motor-vehicle population, 90 million (72%) were added outside the United States.

"It is difficult to single out any one invention that has had a more far-reaching effect on our society and our world," H. J. Gibson, the 1976 recipient of the Society of Automotive Engineers' Horning Memorial Award, said of the gasoline engine in the centennial anniversary year of its invention by Nicolaus Otto.

"The Otto-cycle engine probably has had a greater impact on the way people live than all the political revolutions that have occurred in the 200 years since our country (the U.S.A.) was founded. It has contributed importantly to the freedom of man from heavy labor and long working hours and to his standard of living. Since it powers a 'magic carpet' not far removed from the dreams of Scheherazade, it has given man freedom to move where he wants, when he wants. . . . It has remade the face of the U.S.A. and is rapidly remaking the face of many other countries and the lives of their people."

Judging from rates of motor-vehicle growth during the present survey period, millions of the world's people are discovering the wonders of the "magic carpet" for the first time. Many millions

more will do so in the remaining years of this century.

The implications for the international petroleum-refining industry seem quite clear. Hydroskimming-type refineries consisting of little more than distillation facilities and a catalytic reformer to upgrade virgin naphtha to gasoline no longer will be able to meet consumer demand. Catalytic crackers, hydrocrackers, cokers, and other conversion units will be needed to make more naphtha-range product. This would be true even if gasoline were the only finished product competing for the naphtha available. However, as has been seen, most of the world's petrochemical needs also will have to be met with naphtha during the foreseeable future.

Thus, it appears that the peaceful "magic carpet" revolution now in progress will, of necessity, spark a turnover in world petroleum-refining patterns from emphasis on heavy fuel oils to emphasis on gasoline and petrochemical feedstocks. Fortunately, the basic technology for the refining-industry's reorientation already exists and has been highly developed in meeting similar requirements that arose in the U.S.A. some years earlier. Not all will be simple, however. In an era of high crude-oil prices and eventually dwindling supply, nations cannot afford to meet product requirements via routes that waste energy resources. Thus, joint study and cooperative action between energy planners and environmental planners will not only be desirable, but essential.